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# Temporal and Spatial Influences on South Dakota Farm Economies of Size

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# TEMPORAL AND SPATIAL INFLUENCES ON SOUTH DAKOTA FARM ECONOMIES OF SIZE

BY

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This thesis is approved as a creditable and independent investigation by a candidate for the Master of Science degree and is acceptable for meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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# ABSTRACT

TEMPORAL AND SPATIAL INFLUENCES ON SOUTH DAKOTA FARM ECONOMIES OF SIZE

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Census of Agriculture data are evaluated to test for economies of size of South Dakota farms. Economies of size occur when per-unit costs decrease as the size of a firm increases. This research measures technical economies of size, which assume that all firms pay identical input prices and receive identical output prices. The dependent variable of the model is expenses per dollar of sales. This is a typical measure of efficiency in agricultural statistics. The data come from the four prior Census of Agriculture years, 1997, 2002, 2007, and 2012. A state-wide model and a county-wide model were developed to test for economies of size of South Dakota farms.

Evidence of economies of size was found at both the state and county levels. The state-wide model suggests that economies of size are present on farms with sales of approximately $100,000 or greater. An important implication of this finding is that a large proportion of South Dakota farms appears to be achieving economies of size.

The county-level model was used to further analyze factors that were postulated to influence economies of size and farm efficiency. By controlling for both spatial and temporal influences, it was found that the higher the proportion of crop sales, and the higher the proportion of farms with over $100,000 in sales, the more economically efficient farms by county were found to be. Specifically, a one percent increase in the proportion of crop to total county sales was found to decrease expenses by $0.12 per

dollar of sales, *ceteris paribus*. Similarly, a one percent increase in the proportion of farms with over $100,000 in sales was found to decrease expenses by $0.14 per dollar of sales, *ceteris paribus*.

The main findings of this research are: 1) a large number of farms in South Dakota show evidence of economies of size, 2) counties with higher average farm sales show advantages in farm efficiency over counties with lower average farm sales, and 3) counties with a higher proportion of crop sales have lower expenses per dollar of sales. During the sample period, large shifts in farm size and cropping practices occurred. Specifically, large increases in acres of soybeans and corn were observed along with significant increases in commodity prices. These factors certainly influence the results shown in this research, and will continue to influence the structure of agriculture in South Dakota.

# Chapter I: Introduction

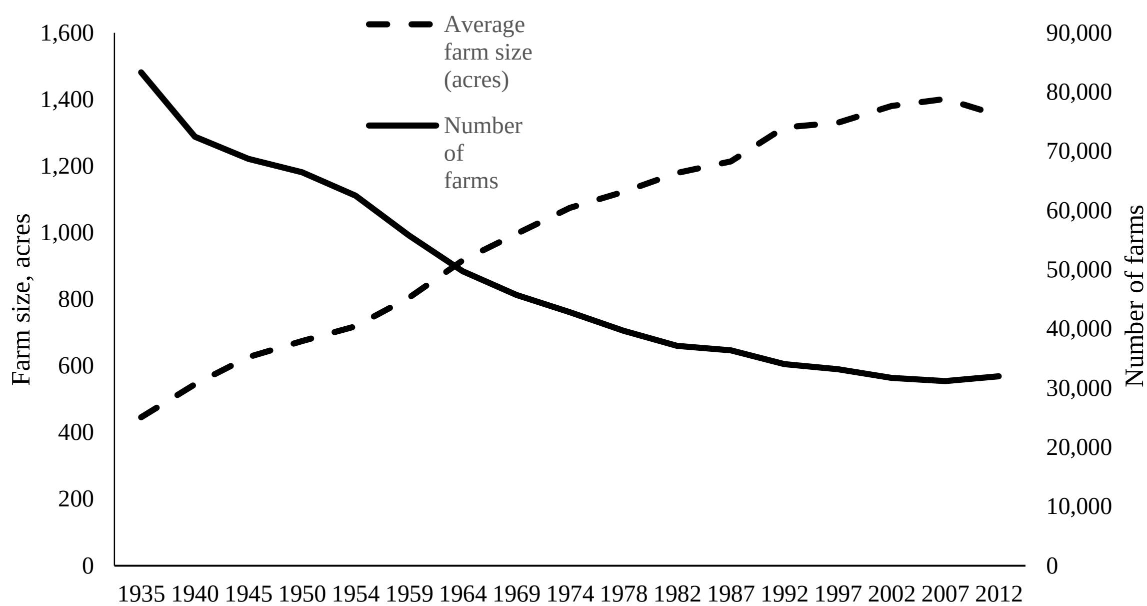
Increasing farm size and a decreasing number of farms have been structural trends in the United States for decades. In 1950, the U.S. had over 5.0 million farms that averaged 216 acres in size. By 2012, the number of farms decreased to just over 2.0 million and average farm size increased to 434 acres. Labor-saving technologies, improved farm infrastructure, changing farm demographics, and other factors have caused an increase in farm size. In addition, economies of size and scope may explain the growth in the size of farms. Previous research has provided evidence of economies of size in agriculture. However, the focus of previous research has been geographically broad.

The growth of farm size is particularly pronounced in specific regions of the U.S. Between 1950 and 2012, the number of farms in South Dakota decreased from 66,452 to 31,989 and average farm size increased from 674 to 1,352 acres (Figure 1-1). The purpose of this research is to analyze farming operations in South Dakota for evidence of economies of size and scope. Innovative research on the size and scope of farms will ensure the continued success of the agriculture industry in South Dakota.

In 2012, South Dakota ranked 6$^{th}$ in corn for grain and wheat acres, 8$^{th}$ in soybean acres, and 7$^{th}$ in cattle and calves inventory among U.S. states, making it a major producer of agricultural commodities (2012 Census of Agriculture).

The changing size and structure of farms in has many implications. A small number of farms now produce a major portion of total agricultural output. This has led, and may continue to lead, towards an uneven distribution of wealth in the farm sector. If large farms have a competitive advantage, they will continue to capture the benefits of increasing size. Due to farm consolidation, there is concern for a slowdown in farm productivity at many levels (Sumner, 2014). Economies of size and scope can in part inform some of the trends that are occurring and will occur in South Dakota agriculture.

Figure 1-1. Average farm size and number of farms in South Dakota, 1935-2012




Source: U.S. Census of Agriculture

Economies of size are achieved when a farm operation reduces cost per unit of production by expanding the farm operation size. Economies of scope are achieved when cost per unit of production is reduced by expanding the number of enterprises on the farm operation. Economies of size and scope may be achieved simultaneously on a farm operation. For example, a farm operation may buy or rent additional land to produce a different crop or livestock, and increase gross returns per acre proportionally more than total costs per acre, therefore reducing cost per unit of production.

Economies of size and scope deal with the efficiency associated with different farm sizes and the number of enterprises on farms. This means that economies of size and scope relate to the cost economies of farm operations. Cost economies can be measured by per-unit costs over a range of farm sizes (Miller, Rodewald and McElroy, 1981). By measuring the relationship between physical inputs and outputs, and assuming all farm sizes receive and pay identical prices on those inputs and outputs, farm efficiency can be measured across a range of farm sizes.

Economies of size and scope are directly related to the cost function of farm operations, and have the potential to affect the profit of individual farms. In its basic form, profit is defined as total revenues minus total costs. If economies of size and scope lead to greater cost efficiencies, they have the potential to increase profit over a range of farm sizes. However, economies of size and scope are only two factors that drive profits. Small farms may have similar cost efficiencies to those of larger farms, but profits of small farms may be limited by a low volume of production that is not limited by cost efficiencies.

Previous research has shown that small farms may be as cost-efficient as large farms. Cost efficiencies allow these farms to meet cash expenses, and return a small profit. These farms may continue to exist if there are viable other income sources that can supplement farm income. However, the growth in farm sizes and decrease in the number of farms in South Dakota show that these small farm operations are either growing in size to remain competitive, consolidating into larger farm operations, or being sold and bought by other farm operations that are able to expand.

Farm sizes in South Dakota have grown over time for a number of reasons. Economies of size and scope are two reasons for the observed growth in farm size. Based on survey results from the “South Dakota Agricultural Land Market Trends 1991-

2015", farm expansion has been either a primary or secondary leading reason listed by farm operators for purchasing farmland in all 25 years of the annual survey (Janssen, Davis and Inkoom, 2015). Therefore, economies of size and scope may influence farm size in South Dakota.

By controlling for other variables, per-unit costs can be compared across farm sizes in South Dakota. Additionally, by using the Census of Agriculture, economies of size and scope can be measured both spatially and temporally. The Census of Agriculture is the most comprehensive survey of agriculture, and is conducted every five years. Data are collected for farm operations that sell or potentially could have sold $1,000 dollars of agricultural products during the Census year. State and county data is collected, allowing for spatial comparisons of farm size. By comparing the cost-efficiencies, as measured by economies of size and scope, a better understanding of farm structure in South Dakota may be deduced.

## Problem Identification

The growth and vitality of the agricultural sector have long been important U.S. policy goals. Dating back to the dawn of the nation, important events surrounding agriculture have influenced the sector today. Thomas Jefferson was a stalwart for family farms and for private citizen ownership of land. He also helped to support growth in family farms. In the early 20$^{th}$ century President Roosevelt formed the Country Life Commission which addressed issues of poverty in rural America and improved productivity on farms by substituting capital for labor. During the first half of the 20$^{th}$ century, technological advances continued to increase farm productivity and new labor-saving technologies were developed. In 1954, the U.S. Department of Agriculture, under the direction of President Eisenhower, wrote a report on the state of the agricultural economy which concluded that the expansion of farm size by the use of labor-saving technologies was needed in order to spur agricultural productivity (Duffy, 2009).

Following World War II, technological advances occurred at a rapid pace. These advances were driven primarily by increased mechanization and availability of fertilizer and chemical inputs. As a result, increased economies of scale drove a rapid increase in the average size of farms and contributed to a decline in the number of farms and of rural populations (Dimitri, Effland and Conklin, 2005).

A decreasing number of farms and a growth in farm size prompted studies of farm structure shortly after World War II. Specifically, studies regarding economies of size, scale and scope were undertaken beginning primarily in the 1960's (Carter and Dean, 1961; Madden, 1967). These studies occurred during a time of farm expansion driven by technological advances.

Interest in this area of research continued throughout the 1980's and into the early 1990's. However, following this period, there was less emphasis on economies of scale in academic research. A shift occurred at the start of the 21st century. Technology once again came to the forefront of agriculture, with advances in biological, chemical, and mechanical technology. In addition, structural changes were occurring in agriculture. Major forces of change included the rapid expansion of the ethanol industry, vertical integration of commodity production, changing consumer tastes and preferences, expanding international trade, increasing agricultural land values, and shifting farm demographics.

Farm efficiency brought about by technological and structural changes has become an important issue in the last decade. Meeting growing global food demand is an important topic in agricultural policy decisions. As a result, agricultural economic research may again focus on farm efficiency and productivity.

This research focuses on farm efficiency and productivity as they relate to production economics for South Dakota commercial farm operations. Specifically, economies of size and scope are analyzed for commercial farm operations. Economies of size occur when the per-unit average cost of production declines as the size of a farming operation grows. For example, a commercial farming operation growing 1,000 acres of corn may have a lower per-unit average cost of production compared to a farm that grows 500 acres of corn, resulting from more efficient use of machinery and labor by the large operation. Economies of scope measure cost savings that occur with the simultaneous production of goods relative to the cost of producing the goods individually (Fernandez-Cornejo et al., 2007).

Economies of scale and size are often intermingled in agricultural discussions. However, there is an important distinction. When measuring economies of scale, all inputs are increased by equal-proportionate amounts. If the per-unit costs increase (decrease) in response to an increase in output, economies (diseconomies) of scale are present. Because farms are unlikely to increase all inputs by equal proportions, economies of scale can be a limiting measure. Economies of size is often used in place of economies of scale, as it measures the change in unit costs associated with a change in some or all of the firm’s inputs (Vlastuin, Lawrence and Quiggin, 1982).

A long-run average total cost (LRAC) curve is often used in studies involving economies of size. Specifically, the shape and the position of the LRAC curve are analyzed for varying levels of output. In microeconomic theory, the LRAC curve is typically displayed in a U-shape form. This LRAC curve is characterized by a negative slope for a substantial portion of the output range, portraying increasing returns to size, followed by a constant slope in the output range, portraying constant returns to size, and finally a positive slope at a higher output range, portraying decreasing returns to size. One explanation for the rising part of the LRAC curve is fixed managerial ability. This occurs when there are diseconomies of management, in which manager ability becomes insufficient at a certain size of farm operation, leading to increasing average costs (Alvarez and Arias, 2003).

The LRAC curve for certain agricultural enterprises may not take the classical U-shape form. Instead, economies of size may exist for a certain range of output. After some level or “cutoff point”, they dissipate and average costs tend to become constant (Alvarez and Arias, 2003). This LRAC curve is often described as L-shaped. This may occur when unit costs are relatively constant over a wide range of outputs.

Constant unit costs may or may not occur in certain farming enterprises. Large farm operations may obtain volume discounts on large purchases, leading to lower input prices, and a decline in average costs as the farm size increases (Alvarez and Arias, 2003). This is often called pecuniary economies. Pecuniary economies are said to exist if larger firms pay lower prices for their inputs compared to the prices smaller firms pay for their inputs. This can occur because of lower transaction costs and greater bargaining power, which can in turn lower average costs (Chavas, 2001).

Therefore, it is important to mention the varying combination of factors that can affect the LRAC curves of farm operations. These include: managerial ability, volume discounts on inputs, technological adaptation, and other size-specific agricultural practices. Inclusion of these variables in empirical analysis can be challenging. Often, proxy variables are used in place of direct measures.

## Research Objectives

The overall objective is to empirically test for economies of size and scope for commercial farm operations in South Dakota. The presence of economies of size and/or scope will give insights into farm profitability and likely structural change that can then be used for future policy decisions.

Specific research objectives include:

1. Assess the presence of economies of size for the major farm types in South Dakota,
2. Investigate the presence of economies of scope for South Dakota farms,
3. Analyze regional differences of farm size, productivity, and growth across South Dakota, and
4. Evaluate the effect of farm size and diversification on farm financial performance.

## Justification

A growing global population has placed increasing demands on U.S. agricultural production. To meet these demands in the future agriculture must produce as efficiently as possible to maximize production using scarce resources. There are many factors affecting agriculture today. A few of the main factors include: changing costs and structure in production agriculture, a rise in consumerism, a growing global marketplace, intensified concerns about environmental impacts, a declining farming population and political influence, and increased private sector research and development (Martin, 2007).

The Economic Research Service (ERS) is part of the USDA, and one of its foci is on issues surrounding farm structure and organization. Areas of research that the ERS has focused on include the structure and finance of U.S. family farms, agricultural contracting, and characteristics and production costs. The research in this paper provides a similar approach, in which economies of size and scope are empirically analyzed for South Dakota farms. This may provide helpful information regarding farm structure and organization in South Dakota.

This study is beneficial for a number of groups. First, knowledge of economies of size and scope may provide guidance for how public policy can impact growth at the farm level. Second, from a farm business perspective, economies of size and scope may identify factors that impact size, diversification and financial performance of farm operations. Third, from an academic perspective, this paper extends research specific to economies of size and scope; a model framework that has provided useful insights in the agriculture sector for many decades.

By measuring economies of size and scope for commercial farms in South Dakota, insights into current farm structure can be obtained. Farm policy makers will benefit from this research through an improved understanding of the underlying influences on farm structure. Predictions of farm-level growth and structure can then be deduced. Additionally, there is a common perception in agriculture that large farms outperform small farms. This has the potential to influence resource allocation at the farm and legislative levels (Hadrich and Olson, 2011). Without a thorough understanding of these issues, and adequate empirical evidence to support any claims, there is potential for improper resource allocation.

As agriculture and farm structure continues to change, predicting trends in farm growth, attrition, and diversification becomes challenging. An objective of this research is to inform some of these issues. By observing trends in economies of size and scope of South Dakota farms, it may be possible to predict trends. If certain regions of South Dakota or certain enterprises (e.g., grain farms or cattle farms) are shown to have significant cost advantages, it may be possible to predict trends in farm growth.

There is widespread interest in the sustainability of family farms in South Dakota. However, there is little information comparing economies of size across farm types in South Dakota. If it can be shown that a typical family farm in South Dakota captures economies of size or scope, then policies intended to preserve family farms have a stronger economic backing.

Along with family farms, there are strong livestock interests in South Dakota. Cattle have been a staple enterprise in South Dakota for decades, and make up a large portion of total farm revenues in South Dakota. Recently, other animal enterprises such as dairy and poultry have grown in South Dakota. However, crops such as corn and soybeans have seen significant growth in the last decade in South Dakota. This research may be able to inform some of the growth observed in crops, and objectively compare the cost efficiencies of crop versus animal production. By analyzing economies of size and scope of different enterprises, it may be possible to observe trends in past growth of certain enterprises, while at the same time predict growth in farm size, both spatially and for specific farm enterprises.

Retaining farmer operators is an important policy goal for South Dakota. The population of South Dakota agricultural operators contains a large proportion of relatively old operators who control a major portion of agricultural land. The next decade will likely see a large shift in farm demographics as older operators retire. The trend of increasing farm size coupled with the loss of older operators will pose new challenges for younger operators and policy makers.

Barriers to entry for new farmers and financial hurdles for small family farms wishing to expand may increase in the coming decade. The cost of capital for beginning farm operations is often unjustifiable with regards to the risk of expansion. Available farm loan programs and borrowing capacity for many new farmers and farms wishing to expand provide only a portion of the capital needed on farm operations. To justify the expansion of these programs, it is important to provide empirical evidence regarding farm size and structure.

Existing farm operations will also benefit from this research through improved knowledge of farm economies and varying combinations of enterprise productivity across South Dakota. Farmers are often interested in long term-planning for their operations. Information on economies of size and scope may inform how farm size and enterprise diversity can affect farm efficiency and profitability.

Previous studies have analyzed economies of size and scope in commercial agriculture production. However, to date minimal research has been completed on this subject specific to South Dakota. Analyzing underlying trends in increased farm size and efficiency of varying combinations of production enterprises in South Dakota is an important objective of this research.

There are four succeeding chapters in this research. Chapter II is a literature review, composed of previous relevant literature on economies of size, scale and scope in agriculture. Chapter III presents the theory and methods of analysis used in this research. Chapter IV presents both the results and the discussion of the results. Chapter V concludes the research with summary statements and possible extensions of this research.

# Chapter II: Literature Review

In this chapter literature is reviewed in the following areas: 1) agricultural industry research provided by the U.S. Department of Agriculture (USDA) and other sources; 2) studies on size and structure in the agriculture sector related to farm performance, growth, and structural change; and 3) studies on economies of size, scale, and scope.

## Industry Research

South Dakota has experienced an evolution of the farming industry, similar to what has been seen in the United States. The number of farms in both the U.S. and South Dakota has decreased for decades, and the average size of farms has grown. In addition, significant increases in the productivity of agriculture have influenced the well-being of the average U.S. citizen (Hallam, 1993). Studies focusing on the size and structure of agriculture are important for a variety of social and political issues, including the principal goal of sustainable food production.

The livestock sector in the U.S. has seen a large shift in farm size. Livestock production has shifted to much larger and specialized farms, from small diversified farms that were typical in the 20$^{th}$ Century. Financial pressures have driven the specialization of the livestock sector. Typically, large operations have lower costs and higher returns than small operations, driven in part by scale economies. MacDonald and McBride (2009) found that between 1987 and 2002, the production locus - defined as farm size in annual sales at which one half of national production comes from larger farms and half from smaller - increased by 60 percent in broiler, 100 percent in fed-cattle, 240 percent in dairy, and 2,000 percent in hog production. While many of these operations are family owned, a large percentage are involved in contract raising, joint operating arrangements, and other production contracts driven by vertical integration in the livestock sector (MacDonald and McBride, 2009).

Cattle farming and ranching is the largest livestock industry in South Dakota. Large amounts of agricultural land suitable for grazing cattle provides a production advantage for cattle producers. In the U.S. the majority of cattle are raised in the Southern Plains. These areas have relatively long grazing seasons and are less reliant on supplemental feed sources during winter. Nonetheless, despite shorter grazing seasons and higher feed costs, cattle farms in the Northern Plains (including South Dakota) are able to compete with producers in the South due to production efficiencies and economies of size (McBride and Mathews, 2011). Therefore, farms have an incentive to expand, but may be limited by financial constraints. Typically, land suitable for cow-calf production is land that could be converted to cropland, and as crop prices rise the opportunity cost of using land for cattle production rises as well. This has limited the overall expansion of cattle farms in certain geographical locations.

Additionally, farms with beef cows do not always specialize in cattle production. In 2008, cattle production was less than 40 percent of the average farm product value on U.S. beef-cow calf farms in the U.S. and in the Northern Plains (McBride and Mathews, 2011). This result is supported by Nehring et al. (2014), who studied the economic and financial success of U.S. cow-calf operations. They found that diversification in beef production leads to greater asset efficiency, suggesting that other farm enterprises are complementary to beef production.

Diversification can be viewed both at the farm level and at the farm household level. Farm level diversification involves various agricultural commodities raised on an individual farm. Farm household level diversification involves obtaining income from farm production and from off-farm sources. In recent decades, there has been an increasing trend of farm operators and their spouses seeking off-farm income. These farm operators may seek off-farm employment to supplement farm income as well as obtain fringe benefits from employers, such as pensions and health insurance. Fernandez-Cornejo et al. (2007) found that operators of smaller farms are more likely to have off-farm employment, work more hours off-farm, and have higher off-farm income than operators of larger farms. Additionally, they found that high off-farm income is significantly related to adoption of technologies such as yield monitors, herbicide-tolerant soybeans, and other labor-saving technologies. This shows that operators may substitute management time for off-farm labor by increasing their use of physical capital.

Antoni, Khanal, and Mishra (2014) test the assumption of perfectly substitutable farm labor. They divide farm labor into hired labor without an ownership claim, and family labor having ownership claims. Family labor tends to have more knowledge of the specific farm operation, while hired labor may need to be trained for specific tasks. The authors found that the largest farms have the highest degree of substitutability between hired and family labor. Intuitively, this makes sense because large farms typically have high degrees of mechanization and standardized tasks, which hired laborers can be specifically trained for. They found that corn farms have a lower degree of substitutability between hired and family labor than other crop farms and animal farms. Implications of their results indicate that large farms can substitute family labor for hired labor, and in turn devote more time to off-farm labor and leisure. As the farm population ages, the degree to which hired labor can be substituted for family labor will become increasingly important.

O'Donoghue et al. (2011) found that in U.S. agriculture, changes in input use, business arrangements, farm structure, and production practices increased overall output of farm operations without increasing the use of total inputs. The authors used data from 1987 to 2007 from the USDA Agricultural Resource Management Survey (ARMS). Between 1987 and 2007, land used in agriculture decreased from 54 percent to 51 percent of total U.S. land area, while hired labor and operator labor decreased 30 and 40 percent, respectively. Despite decreases in two of the major inputs in agriculture production, productivity has maintained a linear growth pattern over time, primarily driven by using technology. In addition, the technological changes that have occurred in agriculture have allowed farms to increase the size of their operations.

The increasing use of technological inputs is supported by Wang et al. (2015), who found that in the U.S. the prices of farm machinery, energy, chemicals, and purchased inputs all fell relative to the price of farm labor between 1948 and 2011. The lower relative prices increased the use of these intermediate inputs, decreased the use of land and labor, and encouraged farmers to substitute chemicals, custom work, energy and machinery for labor. Increased use of technology and efficient inputs spurred agricultural output by 1.49 percent per year between 1948 and 2011, while growth in total input use grew by only 0.07 percent per year. The authors also found that total factor productivity (TFP), which measures the contribution from all inputs in production, grew by about 150 percent between 1948 and 2011. Productivity growth is important because it drives growth in agricultural output. Slowing productivity growth might increase food prices, raise food insecurity, and potentially increase environmental damage if farmers would have to intensify the use of land and inputs to keep up with demand (Wang et al., 2015).

## Studies on Size and Structure in Agriculture

Hallam (1993) contributed a comprehensive study of American agriculture. He writes, "The most compelling motivation for the study of industry structure is its potential impact on socio-economic welfare. The way in which agriculture is organized has the potential to affect productivity, long run growth, and the stability of food supplies to name just a few elements of socio-economic well-being" (Hallam, 1993, pg. 2). Furthermore, in competitive industries such as agriculture, economic theory implies that with constant or increasing costs, firms will earn zero economic profits and products will be priced at minimum average cost. Therefore, if firms have declining costs, the size of firms tends to grow and competition may break down. Agricultural production of raw commodities is often viewed as a perfectly competitive market, and a move towards larger farm sizes is sometimes viewed as a breakdown of perfect competition and a move towards monopolization. The potential for such market changes creates interest in studies of size economies and other forces in the agriculture sector (Hallam, 1993).

Hallam (1993) explained the direct and indirect effects of firm size and structure relating to the agriculture industry. He concludes the structure of farms may directly affect individual profitability, producer welfare, and international competitiveness and changes in trade. As the structure of agriculture shifts towards fewer and larger farms, there are periods of adjustment in optimal size and technology, which may result in individual firms, or farms, having differing rates of profit. These effects may be smoothed out over the long run, but in the short run there are possibilities for significant wealth effects. In addition, increasing the size of the farm may be necessary to provide a sustainable amount of family income, which in turn directly affects farm structure and producer welfare (Hallam, 1993).

Indirect effects of farm size and structure also have an impact on societal welfare in a number of ways. The rate of technology adoption may be affected by farm size, because large farms may adopt new but more costly technologies, because they are able to spread costs over more units of output. Stability of the food supply and food safety may also be indirectly affected by farm size and structure. Hallam (1993) contends that an industry with a relatively large number of producers may be able to supply food in both good and bad economic times. However, if there are significant economies of size in agriculture, having many small and high-cost firms may not be the best solution to obtain a stable and bountiful food supply. Other indirect effects of farm size and structure may include environmental impacts, and the sustainability of rural communities and way of life as farm numbers continue to fall (Hallam, 1993).

Sumner (2014) provides a more contemporary analysis of the growth in size and productivity of U.S. farms. There are approximately two million farms in the U.S., a number that has changed relatively little in the last three decades. However, because a farm is classified as a unit which “sold or potentially could sell $1,000 dollars in agricultural products during the year”, many farms do not provide substantial amounts of output (Census of Agriculture). Sumner (2014) contends that this definition would equate to selling one-half a milk cow’s production, or approximately one-half a litter of piglets. Sumner (2014) found that in the U.S. approximately 6% of the farms produce

75% of all U.S. output, based on USDA statistics. For this reason his analysis concentrates on commercial farms, or farms that typically derive a positive net income and may have a full-time operator.

The average size of commercial farms that Sumner (2014) analyzes has doubled over the last two decades, when measured by the center of the production distribution. The estimated center of the production distribution occurs at the point where one-half of production is below that point, and one-half is above. In 1987 the center of the production distribution for corn was 200 acres per U.S. farm. By 2007, that number had risen to 600 acres per farm and corn yields had increased by one-third. Farm size growth has also radically transformed some agricultural industries. The average size of a hog farm at the center of the production distribution had 30,000 head in 2007, up from 1,200 head in 1987.

Sumner (2014) presents nine stylized facts and hypotheses for the growth in farm size and productivity during the last two decades, and explains why there remains only a small proportion of large and very large farms in the U.S. These nine hypotheses focus on managerial ability and selection of farm managers as determinants of farm size in contemporary farming enterprises. The hypotheses are as follows: 1) farm average cost curves are generally L-shaped, 2) cost curves are L-shaped but changes in technology have shifted the minimum-cost farm size out over time, 3) consistent with the recognition of economies of scope, farms may grow by adding commodity enterprises with different specific patterns of labor, management, and specialized capital across the year and across the farm, 4) larger farms typically rent land, while smaller farms own more of the land they operate, 5) managerial ability is a lumpy input, which in turn limits scale economies,

6) when the payoff to non-farm opportunities increases relative to the cost of capital, the result is an increase in capital per farmer, 7) managerial capability has become more similar between farming and nonfarm occupations, 8) farms with more-capable managers are relatively larger, and 9) the interaction between technology, managerial replacement and larger farm sizes increases the pace of productivity gains just as productivity changes affect the distribution of farm size.

Because Sumner's (2014) analysis of the growth in farm size and productivity provides a strong base for this research, the following discussion will include a careful review of his work. Of the stated hypotheses numbers, 1-3, 5, and 8-9 apply most directly to this research, because they deal with economies of scale and scope in agriculture and provide an explanation of how they impact growth of both size and productivity of farms.

First, farm average cost curves are generally L-shaped. However, costs tend to fall rapidly as farm size expands for a limited range, and then after a certain size costs efficiencies are less pronounced. Therefore, large and very large farms may be distributed on other criteria besides economies of scale. Why then do farms grow above a minimum efficient cost size? Sumner (2014) argues it is likely that farms differ in optimal size, and small farms can remain competitive relative to larger farms that have low measured costs, because small farms may have a low opportunity cost of using their human capital in farming. L-shaped average cost curves may also suggest the presence of technology that is not scale neutral, often referred as pecuniary economies (Chavas, 2001).

Technology has also impacted the cost structure of farms over time. Cost curves have remained L-shaped, but changes in technology have increased the size of farms that achieve the minimum-cost size. This is evident by the consistent growth in farm size over time, and the growth in farm size of new farmers in both crop and livestock industries (Sumner, 2014).

Some farm enterprises also achieve growth by adding commodity enterprises across their farms. This is consistent with economies of scope. Farms may engage in rotational cropping systems, such as a corn and soybean crop rotation, with the goal of increasing yields and maximizing the use of inputs such as land and machinery. Diversification also can be used for risk management on farms (Sumner, 2014).

Economies of scale and scope are two compelling hypotheses for the growth in farm size and productivity on a farm. However, specific to individual farms, managerial ability can be a limiting factor depending on the location and the type of farm enterprise. Managerial ability is often considered a lumpy input in the farm production model. Sumner (2014) suggests that human capital is a determinant of farm size, with improving managerial ability helping to explain growth of specific farm industries such as the dairy sector. Across industries that have become standardized, such as dairy, poultry, and other livestock feeding, increasing the number of managers can allow a productive increase in farm size. Farms with relatively capable managers are larger for two reasons: 1) farmers who are more capable compete effectively for land and other resources previously operated by less-capable farm operators; and 2) because returns to managerial ability are high in non-farm occupations, only large farms with potentially the largest incomes can keep and attract the most capable managers.

Superior managerial ability therefore can influence the size of many farms. Increased managerial ability can also interact with other forces that impact farm size, such as searching for lower input prices and higher output prices, managing production risk, and managing hired labor (Sumner, 2014). Therefore, managerial ability is not mutually exclusive of other farm performance metrics that determine farm size and productivity.

Specific studies on South Dakota agriculture have also been conducted. Diersen, Janssen, and Loewe (2000) is a detailed analysis of the structure of agriculture in South Dakota using data from the 1997 Census of Agriculture and previous Censuses. Their report compiled statistics on farm numbers and physical farm size, sales volume and ownership trends, land tenure and ownership trends, farm household and income trends, farm enterprise specialization and diversity, and other farm demographics. By using detailed Census data and other secondary data sources, they were able to examine and explain key changes in the organization and structure of South Dakota's farm sector. Major findings included a declining number of farms in South Dakota, increasing average farm size over time, increasing operator age, increasing farm sales volumes and sales concentration, and increasing non-farm employment trends (Diersen, Janssen and Loewe, 2000). An updated version of this study was completed in September of 2015 (Brown et al., 2015).

## Economies of Size and Scale

Studies of economies of size and scale in agriculture have been done for many decades. Changing farm structure, increasing size of farms, and external forces have all prompted studies on farm efficiency and production. Madden (1967) reviewed selected studies of economies of size for crop farms, specialized beef feedlots, and dairy farms. Analytical procedures such as the synthetic-firm or economic-engineering approach were at the forefront of economies of size studies employed during that time period. The objective of studying the relationship between farm size and efficiency of production still holds true today. Questions posed by Madden pertaining to farm size and production efficiency, the efficiency of large versus small farms, and the economic consequences of size-efficiency relationships remain at the center of agricultural research.

Numerous studies have found that average cost curves for farm operations are generally L-shaped. That is, costs fall rapidly as size of the operation expands for a limited range, but after a minimum size, costs decline very gradually. An L-shaped average cost curve suggests some important points in farm structure. First, economies of size may exist for smaller size farms. Second, there is no strong evidence that diseconomies of size exist for large farms. Third, there is a wide range of farm sizes where costs are approximately constant. This had led to interest in the minimum efficient farm size, meaning, what is the smallest farm size that can capture the benefits of economies of size and/or scale (Chavas, 2001). As mentioned earlier, over time, changes in technology have shifted the minimum-cost farm size, which is consistent with farm size growth (Sumner, 2014).

The evidence is mixed for the returns to scale of farm operations. For example, Mosheim and Lovell (2009) used a cross section of dairy farms to estimate scale economies. By incorporating technical and allocative inefficiencies in their models, their findings show that returns to scale are larger at all levels of output than has been previously shown in other studies. The study employed data from the 2000 ARMS. Estimates of returns to scale relationships across dairy farms of different sizes and from different regions were accounted for by incorporating variables hypothesized to influence farm performance. Their findings show significant returns to scale in U.S. dairy farms, and the preferred cost function used in the study does not show a region of decreasing returns to scale. This helps to explain why the average size of dairy farms has been increasing in the U.S. (Mosheim and Lovell, 2009).

Complications occur when modeling economies of size, and/or scale due to a multitude of reasons. One important variable in any function is managerial ability. Alvarez and Arias (2003) used annual data from a panel of eighty-four dairy farms in Asturias, Spain, observed over the period 1987-1991. Using empirical cost-function and production models, the authors found that managerial ability has an impact on economies of size. Results drawn from a production model show that increasing output with a fixed level of managerial ability can lead to a decrease in profits. What this means is that managerial ability becomes important as farm size increases. Large farms may require more time and expertise to run, compared to smaller farms. The findings of the research stress the importance of managerial ability on farm performance, size, and structure. Additionally, better management of farms may allow farms to increase in size, and capture economies of size.

Proxy variables are often used to control for managerial ability. Many authors, including Alvarez and Arias (2003), use the percent of farm operators with higher education and the number of years of farm tenure as proxies for managerial ability. Although not a perfect measure of managerial ability, the percent of operators with relatively high levels of education and land tenure can control for a portion of managerial ability in an empirical model.

Analyzing economies of size, scale and scope in agriculture can be challenging for a variety of reasons. A major hurdle is the diverse mix of enterprises in agriculture. Cropping systems, cattle farms and ranches, dairy farms, commercial hog operations, and other enterprises all have varying levels of inputs, costs, and levels of production. Results have been shown to be mixed, even within the same industry. Mosheim and Lovell (2009) found no area of decreasing returns to scale in their research of U.S. dairy farms; they found an L-shaped average cost curve. Alvarez and Arias (2003), however, found evidence for diseconomies of scale in Spanish dairy farms when holding managerial ability fixed; they found a U-shaped average cost curve.

One reason for this contradiction is varying levels of technological adoption. Technological change has played an important part in agriculture for decades. Farmers have the option of different technological inputs, and each may be uniquely suited for a particular farm size. Typically, for a given type of technology, average costs will decrease with size up to a certain point beyond which average costs will increase. However, farmers may then adopt new technology that may lower their average costs as farm size continues to increase. This can lead towards a constant average cost across a wide range of farm sizes. This helps to explain empirical evidence that both increasing and constant returns to scale coexist in agriculture (Chavas, 2001).

## Economies of Scope

Economies of scope applies to farm diversification, in which farms are involved in multiple enterprises. A typical diversified South Dakota farm could grow corn, soybeans, wheat, and raise cattle. Economies of scope and farm efficiency may arise from spreading input costs across multiple commodities. This “model farm” may own one combine that uses a corn head and a small grain head so that the cost of the combine is spread across several types of crops. Additionally, tractors and other equipment can be shared across enterprises, which in turn lowers the average total cost compared to farms that are involved in only single enterprises (e.g., raising cattle only).

As farms have become larger and more efficient there is an underlying belief that farms are extremely specialized. That is the case when comparing farms today versus farms 75 years ago that raised multiple animals and grew a variety of crops. But many farms today are still involved in multiple enterprises that allows them to capture economies of scope, maximize resource allocation, and maximize income.

Hadrich (2013) used a panel data set of 114 North Dakota farms from 1993 to 2010 to determine factors that affect farm revenue variation in the Northern Great Plains. One of her findings was that large farms in North Dakota were more diversified than small farms. Farms that had five or more enterprises had an average farm size of 2,885 acres, while farms with four or fewer enterprises had an average farm size of 2,410 acres. North Dakota and South Dakota have seen similar trends over the past decade that include a shift in cropping plans and rotations. The most common trend is the shift towards large market crops (corn, soybeans, and wheat) overtaking small market crops and pasture. At the same time, crop insurance has become more readily available, leading to Hadrich's finding that crop insurance revenues had a positive effect on farm revenue variation, an indication that producers who purchase crop insurance take on more risky crop production strategies. Crop revenue was found to be the largest source of farm revenue variation. Additionally, farm size was found to be a determinant of revenue variation, which suggest that "more efficient" operators are able to increase farm size through increased access to capital and other efficiencies (Hadrich, 2013).

Wu and Prato (2006) investigated the productive efficiency for a sample of Missouri crop-only (specialized) and integrated crop-livestock (diversified) farms. Diversified farms were found to be as technically and scale efficient as specialized farms. However, lower allocative efficiency impacted the overall technical efficiency of diversified farms, which resulted in greater overall cost inefficiency compared to specialized farms. Better financial management and managerial ability was found to enhance economies of scope for crop and livestock farms in Missouri. Additionally, they concur that policies aimed at improving financial management of small farms and/or increasing non-farm employment are likely to increase allocative efficiency and economies of scope for diversified farms.

Fernandez-Cornejo et al. (2007) expanded the concept of scope economies to include both on and off-farm income generating activities as output, in addition to traditional farm outputs. Although large farms were found to be more efficient than small farms in transforming inputs into outputs, when off-farm activities are included total farm household-level efficiencies increased across all farm sizes and were greatest for small farms. Their findings suggest that small farms have adapted to shortfalls in farm-level inefficiencies by increasing their off-farm income.

## Summary

In reviewing the agricultural industry, USDA research reports were examined. MacDonald and McBride (2009) found that vertical integration, along with production contracts, have driven the large increases in farm size in the U.S. livestock sector.

O'Doneoghue et al. (2011) and Wang et al. (2015) found evidence for increases in agricultural productivity despite decreases in the use of land and labor, both major inputs in agriculture production. A decrease in the relative prices of technological inputs compared to the prices of land and labor has spurred the adoption of technology, which has helped increase agricultural productivity.

McBride and Mathews (2011) found evidence of production efficiencies and economies of size in Northern Great Plains cow-calf operations. This allows farms in South Dakota and other states in the region to compete with large cattle operations in the southern United States. Farms in the U.S. and South Dakota remain diversified. Nehring (2014) found that diversification in beef farms has led towards greater asset efficiency. Fernandez-Cornejo et al. (2007) found that small farms had more off-farm employment than large farms, leading towards greater farm-household income diversification.

There are many direct and indirect effects resulting from the changing structure of agriculture. Hallam (1993) summarizes the direct effects, which include producer welfare and profitability, international competiveness, and trade. Indirect effects include environmental impacts, changing food prices, and sustainability of rural communities. South Dakota will be impacted by these changes in agriculture. Diersen, Janssen and Loewe (2000) found a decreasing number of farms, coupled with increasing farm size, older operator age, and increasing non-farm employment in South Dakota over the 1970's to 1990's period.

Related research analyzing economies of size, scale and scope was reviewed concerning changes in U.S. and South Dakota agriculture. Madden's (1967) study of economies of size marks one of the first comprehensive studies in agricultural economics.

Questions posed by Madden relating to production efficiencies and cost-size relationships still apply to agriculture today.

Mosheim and Lovell (2009) found no evidence for diseconomies of size in U.S. dairy farms. In contrast, Alvarez and Arias (2003) found that there are diseconomies of size for dairy farms when holding managerial ability constant. Chavas (2001) suggests that technological adaptation by different sizes of farms is an explanation for evidence of coexisting diseconomies and economies of size.

Hadrich (2013) found that large North Dakota farms are more diversified than small farms, a contradiction to some previous research. This can be partially explained by regionally related differences. Different studies on economies of scope have found that diversified farms are not as efficient as specialized farms (Wu and Prato, 2006) while small farms engaged in both off-farm and on-farm income related activities are more efficient than specialized farms (Fernandez-Cornejo et al., 2007).

# Chapter III: Theory and Methods

In this chapter the theoretical background is presented, providing the basis for the research. Following the theoretical background, the methods and procedures used to interpret the research are explained.

## Theory

The conceptual framework for this research centers on economies of size, scale and scope. Developed in classical microeconomic theory, returns to size, scale and scope come from the theory of the firm under perfect competition, and have been adapted for industry research in banking, business, and agriculture. Perfect competition does not exist in agriculture (or other industries), but the theoretical models developed in economics are applied to depict economies of size, scale and scope.

Returns to scale and returns to size are commonly used when discussing returns to a technology. Assume a production function, as given by Hallam (1991):

$$y = f(x_1, x_2, \dots x_n) = f(x),$$

where y is output and x is the vector of inputs $x_1$ through $x_n$. If f(x) has the usual neoclassical properties of quasiconcavity, strict positive monotonicity, and twice continuous differentiability in x, then the elasticity of scale is implicitly defined as:.

$$\epsilon \; = \frac{\partial \ln f(\gamma x)}{\partial \ln \gamma} \;\; | \;\; \gamma = 1.$$

The above expression shows how output changes as inputs are changed in fixed proportions. This can also be represented by the following expression:

$$\epsilon \; = \Sigma \frac{\partial f}{\partial x_i} \frac{x_i}{y}.$$

Therefore, the elasticity of scale represented in the above expression is the sum of the output elasticities for each input. Decreasing returns to scale are said to exist if $\epsilon < 1$, constant returns to scale exist if $\epsilon = 1$, and if $\epsilon > 1$ then there are increasing returns to scale.

Hallam (1991) describes the relationship between returns to size and returns to scale, "Returns to size is the change in output relative to costs for variations along the expansion path (cost minimizing input combinations) where the input price ratio is held constant. The elasticity of size which is the reciprocal of the cost elasticity with respect to output is defined by":

$$\gamma = \frac{c(y,w)}{(\frac{\partial c}{\partial y}y)} = \frac{AC}{MC}.$$

By this definition the elasticity of size is the ratio of average cost (AC) to marginal cost (MC). If the elasticity of size is greater (less) than one, then the firm exhibits increasing (decreasing) returns to size and the average cost curve is downward (upward) sloping (Hallam, 1991).

Elasticity of size and scale are often depicted by two shapes, U-shaped or L-shaped, which are shown in Figures 3-1 and 3-2, respectively. As mentioned in the previous chapter, there have been different empirical results in regards to economies of size and scale in the literature. Some studies (e.g., Alvarez and Arias, 2003) have found that average cost curves for particular farms exhibit increasing, constant, and decreasing returns to scale, similar to what is depicted in the U-shaped average cost curve in Figure 3-1. Other studies (e.g., Mosheim and Lovell, 2009) have found average cost curves that only exhibit regions of increasing and constant returns to scale, which is depicted in Figure 3-2.

Figure 3-1. U-shaped average cost curve

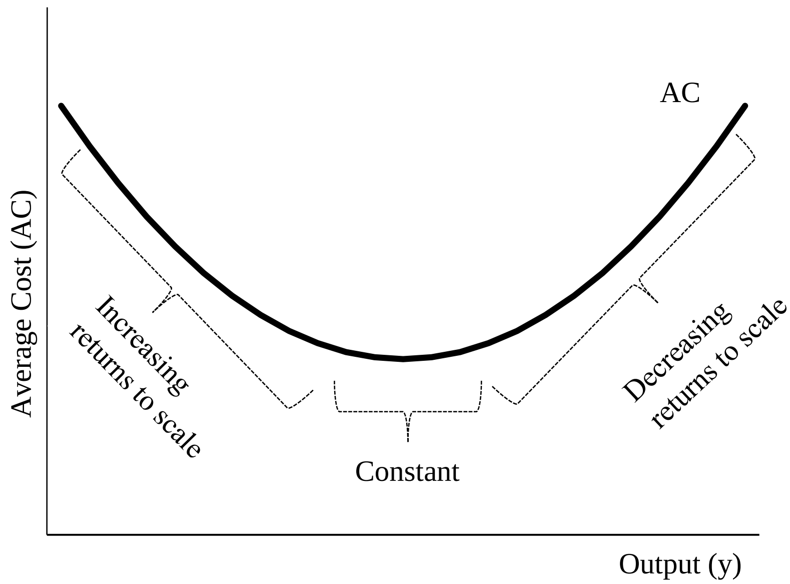
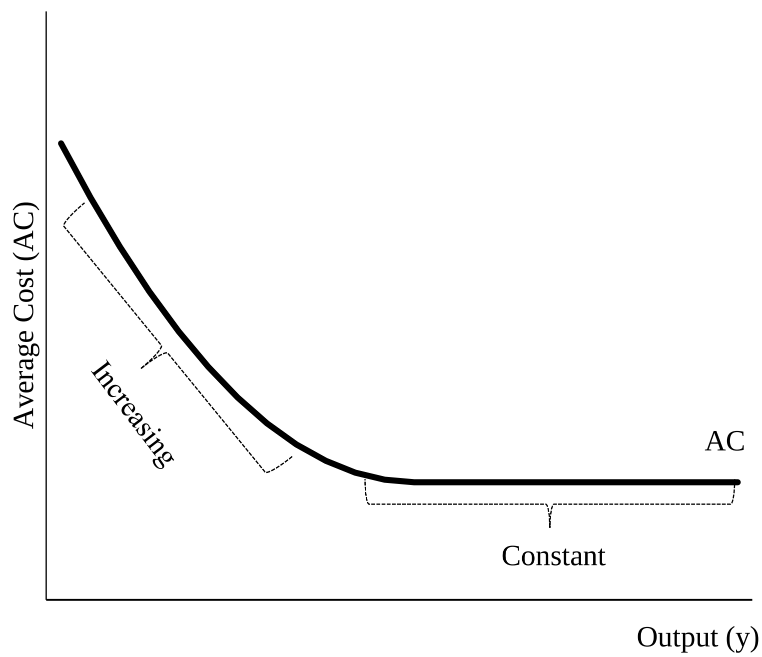



Figure 3-2. L-shaped average cost curve



## Data and Methodology

Many methods have been applied to study economies of size and scope in agriculture. Many studies employ data from individual farm records, farm management associations, and the Agricultural Resource Management Survey (ARMS). Each of these data sources has advantages and disadvantages when applied to empirical research.

For example, Kuethe et al. (2014) find that data collected from farm management associations tend to represent a greater proportion of large farms, and a larger share of crop producers as compared to livestock producers. This is obviously an important issue regarding economies of size and scope. A skewed survey or sample could lead to type I or type II errors in statistical hypothesis testing.

ARMS data employ a comprehensive stratified sampling framework. However, ARMS is a repeated cross-sectional survey where different farms are surveyed each year. Additionally, the questions in the survey change to keep up with changing farm conditions. Finally, many times working with ARMS data requires extensive research expertise due to the USDA's confidentiality requirements and data access restrictions (Kuethe et al., 2014).

The Census of Agriculture provides the most comprehensive and long-run data available in agriculture. The Census is the only source of information that provides uniform, comprehensive, and impartial data for every county in the nation.

The first agricultural census was taken in 1840 and then it was conducted every 10 years up until 1920. Since 1920, the Census of Agriculture has generally been conducted every five years. The U.S. Department of Agriculture, National Agricultural Statistics Service (NASS) took over the Census duties in 1997, which was previously conducted by the Bureau of the Census. In 1997, the North American Industry Classification System replaced the Standard Industrial Classification (SIC) system.

The methodology used in the Census of Agriculture is provided for in Appendix A of the Census. A main goal of the Census is to account for "any place from which $1,000 or more of agricultural products were produced and sold, or normally would have been sold, during the census year." This definition of a farm was first used in the 1974 census, and has been used in all subsequent censuses (2012 Census of Agriculture).

The Census accounts for the very smallest of farms. This is a benefit of the Census, but it also presents challenges. When reviewing and analyzing aggregated data, it is important to consider how the inclusion of very small farms can impact the aggregated conclusions as a whole. To account for this, many researchers only include certain sizes of farms, commonly referred to as "cut-off" farm sizes.

This research uses the Census of Agriculture to empirically test for economies of size and scope of South Dakota farms. The Census has been used previously to test for economies of size and scale. Duffy (2009) used the Census of Agriculture to descriptively show economies of size. He used data from the 2007 census to show distributions of farms by sales class, dollars of farm sales per dollar of farm expenses (a measure of efficiency), and percentage of U.S. farms with positive net farm cash income.

Sumner (2014) used the Census of Agriculture to show a changing size distribution of U.S. farms. He also employed descriptive statistics and figures to show how the larger farms now account for a large proportion of agricultural sales. For example, he found that the smallest 60 percent of farms by sales generated only about 5 percent of sales on average, between 1987 and 2007.

Peterson (1997) used the 1987 census to complete a cross-sectional regression analysis of ten Corn Belt states. He tested economies of scale based on nine sales classes of farms, which are reported in the Census. He found that after accounting for factors such as quality of land and management, farm dwellings, and off-farm employment, small farms are at least as efficient as larger commercial operations. Interestingly, he found that the largest classes of farm had diseconomies of scale. This would be typical of a U-shaped average cost curve.

The previous literature has shown that the Census of Agriculture provides sufficient data to test for economies of size in commercial agricultural production. Additionally, it provides data for every county in South Dakota. This allows for testing hypotheses for both economies of size and scope, as well as spatial differences in production agriculture.

## Conceptual Models

Multiple conceptual models are presented to show relationships between farm profits, production costs, and farm efficiency to economies of size and scope in South Dakota agriculture. A final conceptual model is provided to focus on the relationship of economies of size and scope in commercial agricultural production.

Farm profits are often the most referenced aspect in the agriculture industry, as they are simple to understand and they fluctuate across enterprises and through time. Beckman and Schimmelpfennig (2015) provide a conceptual model of net farm income:

$$Farm\ Income^{t}(\pi) = (Gross\ Margin\ per\ acre^{t})\ x\ (acres\ in\ production^{t}),$$

where farm income in period t is a function of gross margin per acre and acres in production. Gross margin per acre in period t is calculated by taking total revenue per acre less total costs per acre. Acres in production in period t is included to represent acres where final inputs and outputs are used in the production process.

Net farm income is therefore dependent on two main variables, total revenue and total costs. The calculation for total revenue is provided by NASS and shown below:

$$Total\ Farm\ Revenue = f(Agricultural\ sales, Government\ payments, Farm - related\ income),$$

where agricultural sales includes final receipts of crop and livestock sales; government payments include conservation payments, direct payments, loan deficiency payments, disaster payment, and payments from other federal programs; and farm-related income includes payments received for rent, custom work, recreational services provided, patronage dividends, crop and livestock insurance payments, and other activities closely related to farm operations.

Total farm production expenses can be represented by the following equation:

$$Total\ Production\ Expenses = Feed + Livestock\ and\ poultry\ purchases + Fertilizer + Hired\ labor + Cash\ rent + Seeds + Supplies\ and\ repairs + Gasoline, fuels, and\ oils + Chemicals + Other\ .$$

The Census of Agriculture provides the necessary data to calculate both total farm revenue and total farm expenses at the state and county levels. Additionally, data are provided for various farm enterprises in South Dakota, allowing for cross-sectional analysis.

In order to measure economies of size and scope of commercial farms in South Dakota, a conceptual model is developed. The model is based on previous models of production efficiencies constrained by available data from the Census of Agriculture.

There are multiple ways in which researchers have modeled economies of size, scale and scope. Because of the type of data selected for this study, the following model provides the best descriptive method to show economies of size and scope for South Dakota farms. The conceptual model follows below:

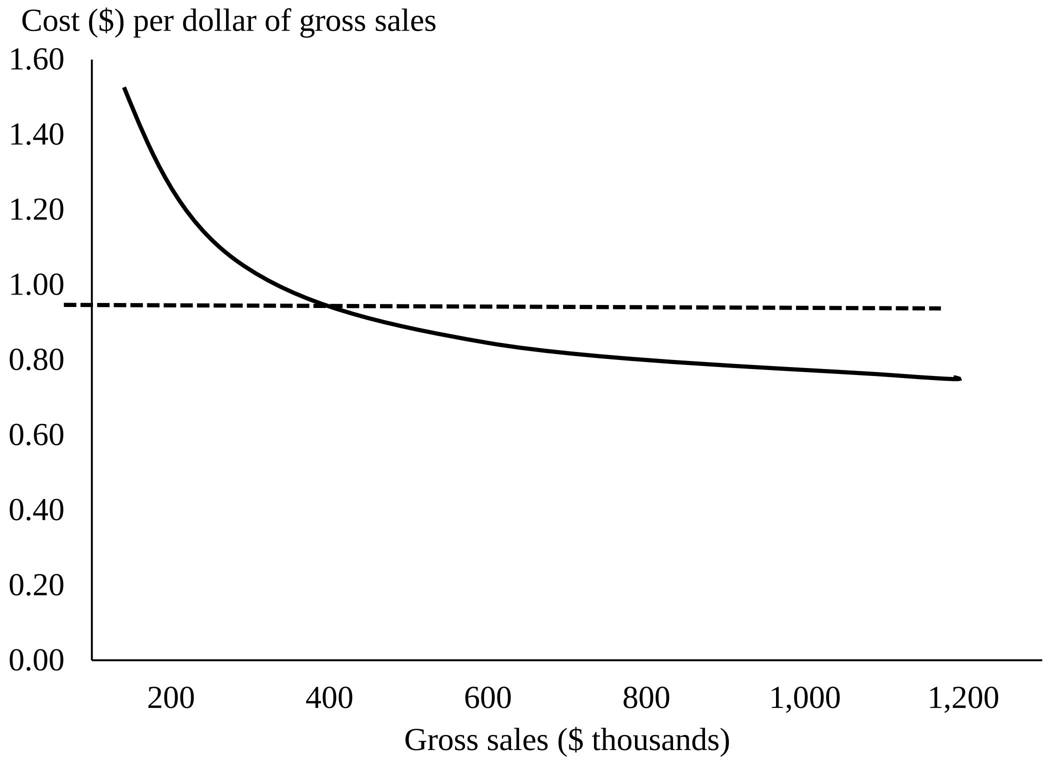
$$\frac{Expenses}{\$\ of\ Sales} = f(size, scope, leverage, technology, rent, managerial\ ability),$$

where size is measured by total farm revenue sales class; scope is measured by diversity or number of enterprises per farm; leverage is measured as interest expenses to total expenses (as a proxy for debt); technology includes fertilizer use, amount of machinery, and crop yields; rent is measured as cash-rent to total expense; and managerial ability is measured by full-time operators (e.g. a full-time operator would have more knowledge of their operation than a part-time operator).

The dependent variable in the model, expenses per dollar of sales, provides a measure of efficiency for commercial farm operations. Intuitively, if larger farms exhibit economies of size, the expenses per dollar of sales will be lower than for smaller farms. The independent variables in the model are included to control for factors that are believed to affect farm efficiency.

To better depict the relationship between cost per dollar of sales and farm size, a graphical representation is shown in Figure 3-3. This graph depicts an L-shaped average cost curve; smaller farms have higher expenses per dollar of sales and larger farms (as measured by sales) have lower expenses. This graph can be applied to different farm enterprises and regions by controlling for the independent variables described in the theoretical model. The dotted line represents the region were expenses equal sales, a proxy for constant returns to scale.

Figure 3-3. Example cost curve for commercial South Dakota farms




<u>Statewide Model</u>

This research uses two models to test for economies of size and scope of South Dakota farms.  The first model uses aggregate state-level data provided by the Census of Agriculture.  The second model uses available county data from the Census of Agriculture.  The reason for using both state-level and county-level data is two-fold. First, state-level data include cross-sectional data by farm size and sales class, which allows for testing of economies of size.  Second, data available at the county-level allows for statistical analysis of economies of size and scope at the regional level.  The data are not as comprehensive at the county level, but based on previous research and economic intuition variables are available to test for economies of size and scope.

Previous research that was discussed in the literature review provides the basis for the state-wide model. Specifically, research from Miller et al. (1981), Sumner (2014) and Peterson (1997) was used to specify the state-wide model. Miller et al. (1981) used cost per dollar of gross income to estimate LRAC for varying crop enterprises throughout the United States. Sumner (2014) provided a detailed account of varying factors that has increased farm size and efficiency in U.S. crop farms. Peterson (1997) used cost per dollar of sales to test for economies of scale across ten corn-belt states, using data from the 1987 Census of Agriculture.

A main objective is to test for the presence of economies of size of South Dakota farms. To do so, a model similar to Peterson (1997) is used. The data for this research comes from the four most recent years of the Census of Agriculture, 1997, 2002, 2007 and 2012. Census years prior to 1997 are not used because beginning in 1997 the classification of what constitutes a farm was changed. In addition, NASS took over the Census administration beginning in 1997. There are many differences in data collection and reporting prior to 1997, making data comparison difficult.

The data collected from the four Census years are categorized by the volume of agricultural products sold. This categorization is commonly referred to as the sales class of farms, as reported by total dollars of agricultural products sold. There are 11 cross-sectional sales classes reported ranging from under $1,000 in sales up to $1,000,000, or more in sales.

The dependent variable in the model is production costs per dollar of sales. Production costs reported in the Census are as follows:

*Total farm production expenses*

Fertilizer, lime, and soil conditioners purchased
Chemicals purchased
Seeds, plants, vines, and trees purchased or leased
Livestock and poultry purchased or leased
Feed purchased
Gasoline, fuels, and oils purchased
Utilities
Supplies, repairs, and maintenance costs
Hired farm labor
Contract labor
Custom work and custom hauling
Cash rent for land, buildings, and grazing fees
Rent and lease expenses for machinery, equipment, and farm share of vehicles
Interest expense
Property taxes paid
All other production expenses

This research focuses on technical economies of size. In technical economies of size all firms are assumed to face identical input and output prices. Therefore, it is assumed that all firms pay identical prices for their inputs such as fertilizer, chemicals and seeds; and receive identical prices for their outputs, such as corn sold. There may also be market economies of size, where efficiencies arise from differences paid for inputs and prices received for outputs. This may occur at some level, such as large farms receiving discounts on large orders of inputs. However, these differences occur at the individual farm level, and cannot be measured with the use of aggregated data. Therefore, any differences in efficiency (economies of size) found in this research would be attributed to technical economies of size.

The conceptual model includes possible variables that can affect farm efficiency and growth at the individual farm level. Factors such as farm size, scope, leverage, technology and managerial ability have all been shown to impact economies of size in some way at the farm level. However, this research uses aggregated data provided by the Census of Agriculture. Because of the nature of the data collection and reporting, certain proxy variables are used in place of direct measures that one might receive from individual farm records. Additionally, certain factors cannot be accounted for at the aggregated level. These include a direct measure of farm leverage typically reported as the debt to asset ratio, the number of farm enterprises on farms (scope), and a measure of managerial ability. Therefore in the models, certain variables are excluded that cannot be directly measured, while proxy variables are included to account for some other factors of farm efficiency.

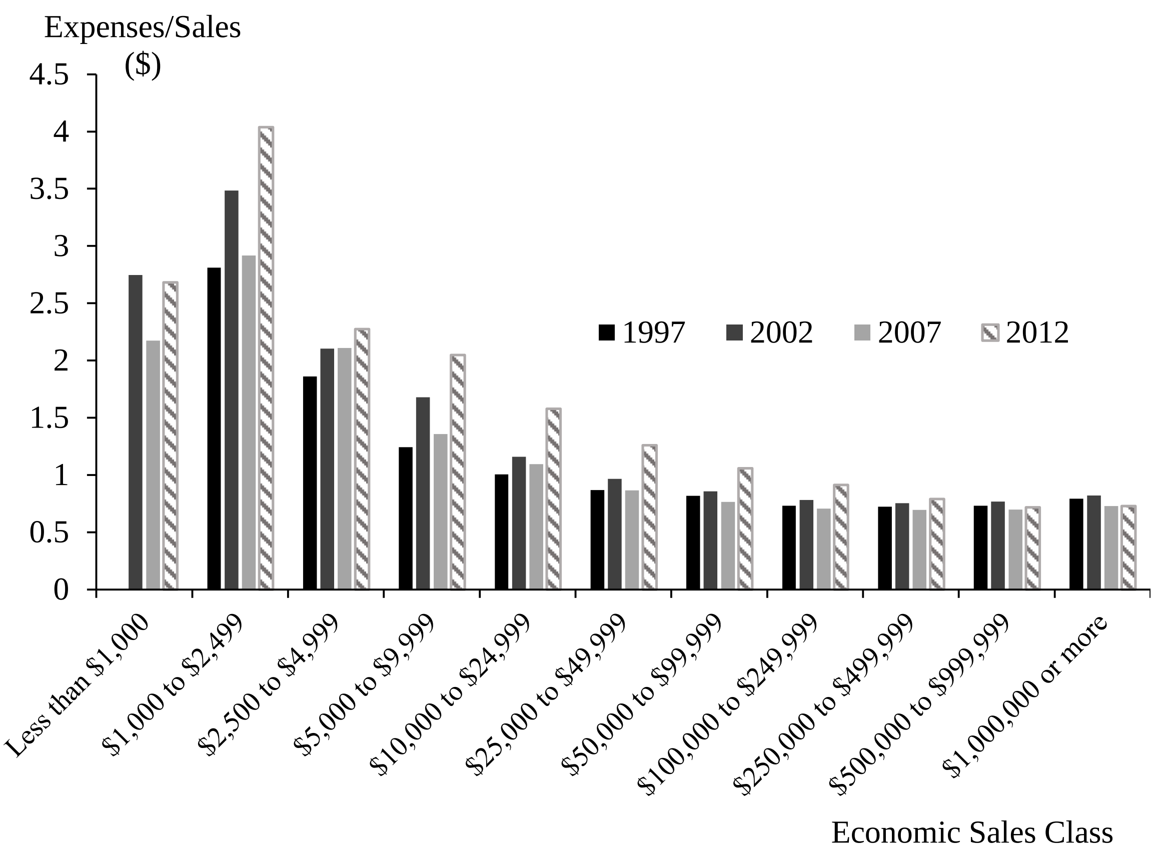
## Descriptive Statistics

The dependent variable used for the state-level model, expenses per dollar of sales, can be used to descriptively show the technical economies of size of the 11 sales classes of farms in South Dakota. The overall trend over the last four Census years shows that as farm size increases, as measured by sales, the technical efficiency of farms increases. In other words, larger farms in South Dakota have lower expenses per dollar of sales than smaller farms do, *ceteris paribus*. It is important to remember that the measure of farm size in this example is the volume of agricultural products sold. There may be some farms with large amounts of acres that have low sales, and vice versa. However, by using this measure a comparison of aggregated farm data allows for a comparison of technical economies of size.

Figure 3-4 shows that farms in South Dakota represent an L-Shaped LRATC. That is, farm efficiency increases as the size of farms increase, then stays constant approximately after farm sizes reach $100,000 in sales or more.

Another interesting notion that can be drawn from Figure 3-4 is the size of farm that achieves "economic efficiency". This can be represented where expenses are approximately equal to dollars of agricultural products sold, or the ratio equals 1. This occurs at farms sizes where sales are $100,000 or greater.

Figure 3-4. Expenses per dollar of sales of South Dakota farms

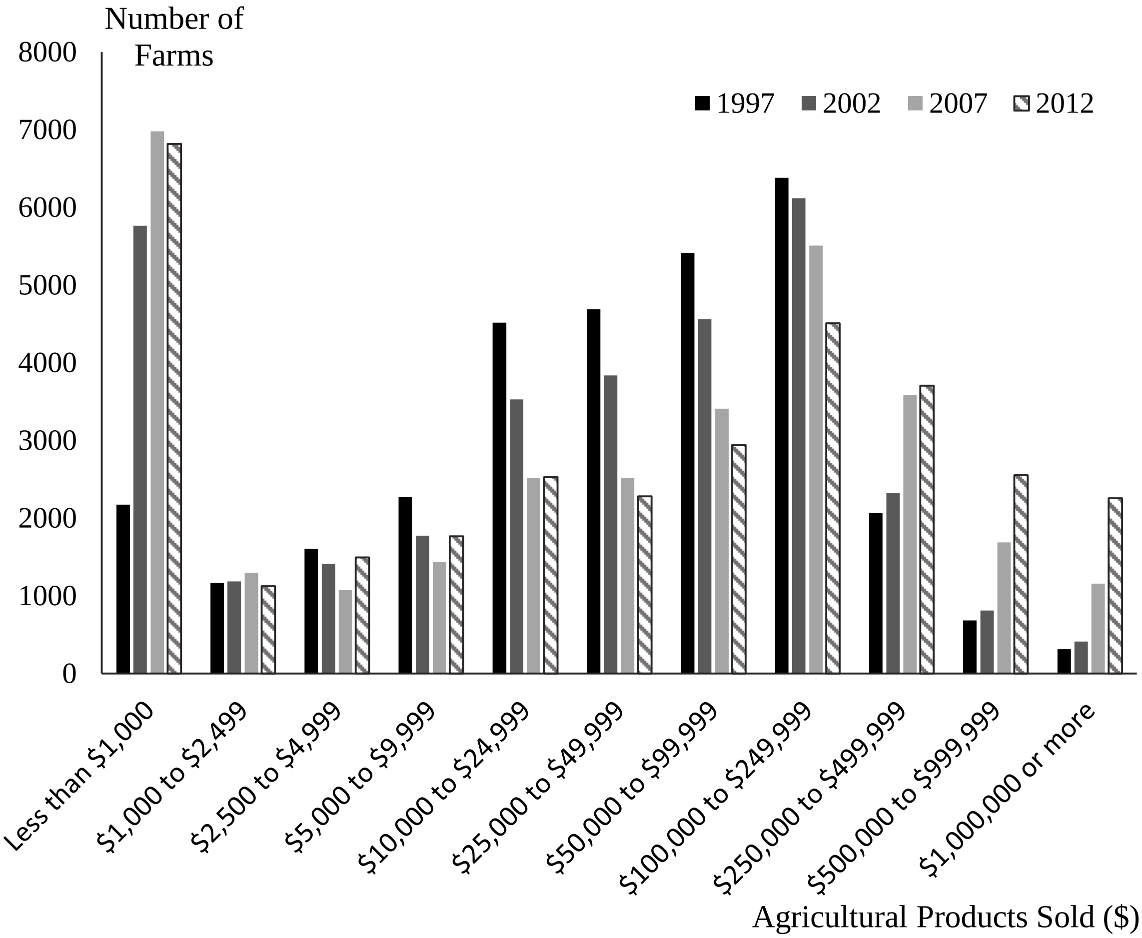



Note: The 1997 sales class under $1,000 observation was not included because it was an extreme outlier, with a value greater than 35.
Source: Census of Agriculture

An implication of the estimated level of farm efficiency is that a large number of farms in South Dakota are producing at an efficient level of production, as measured by technical sales efficiency. Figure 3-5 depicts this well. While there are a large number of farms that produce and sell small amounts of agricultural goods in South Dakota (retirement farms, hobby farms) a large number of farms in South Dakota sell at least $100,000 or more in agricultural products. In 1997 and 2002 approximately 30% of farms sold $100,000 or more in agricultural goods, in 2007 that number rose to 38% and in 2012 approximately 40% of farms sold $100,000 or more in agricultural goods. It is important to note that inflation and rising commodity prices would have an upward effect on the volume of agricultural products sold. However, Figure 3-5 does show that a large number of farms are reaching what may be deemed an efficient farm size in South Dakota.

The other caveat shown in Figure 3-5 is the number of farms that have agricultural sales between $10,000 and $99,999. In aggregate it does not appear that these farms are producing as efficiently compared to larger farms. This may mean that these farms will grow in the future and capture economies of size, or it may mean there will be continued farm consolidation. Either way it appears that at the state-level there may be additional farm size growth in the future.

Figure 3-5. Number of South Dakota farms by sales class



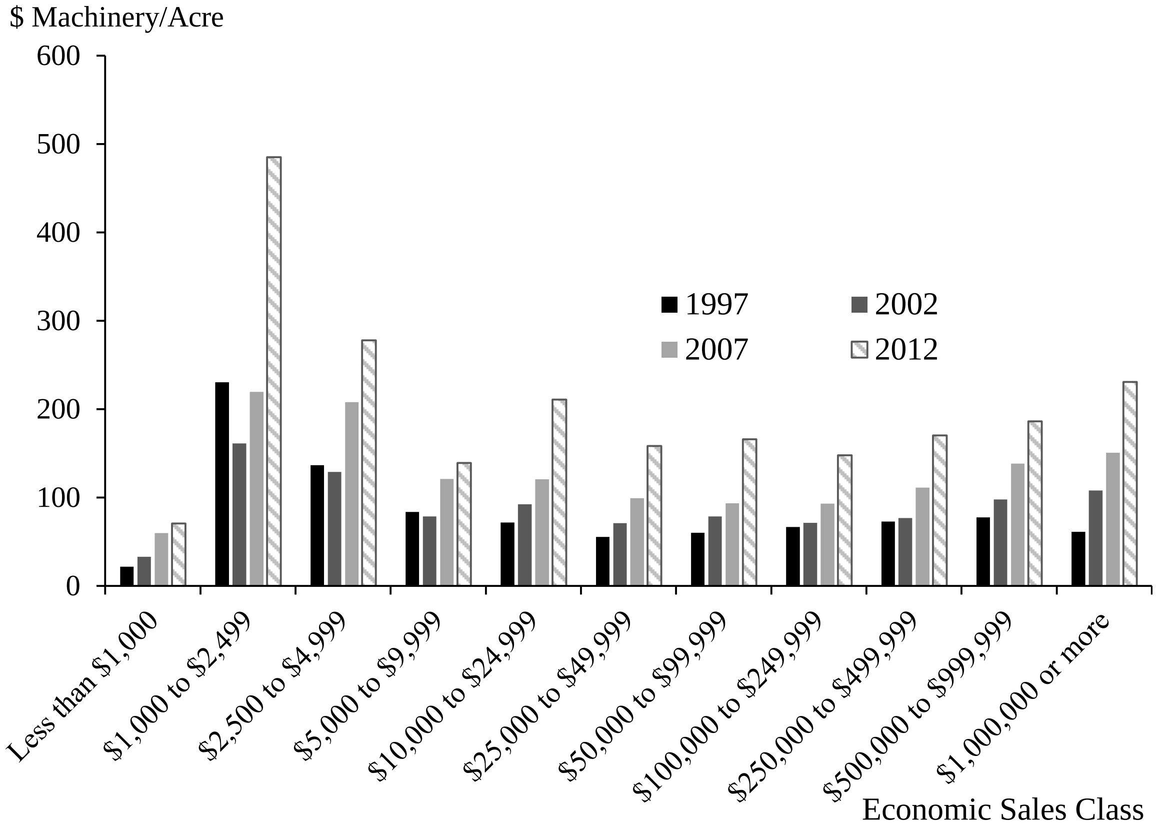

Source: Census of Agricultural

Another variable that can be used to measure or compare economies of size of farms is machinery investment per acre of land. The Census of Agriculture reports the value of machinery and equipment on farm operations. For each sales class the total value of machinery and equipment was divided by the number of total acres in each sales class. This gives an aggregate measure of machinery investment per acre. Intuitively, if machinery value per acre is different across farm sizes, there may be evidence for economies of size and scope. For example, smaller farms may have higher machinery values per acre because they cannot spread the value of machinery across a large number of acres, compared to larger farms. Alternatively, some farms may be able to spread the value of machinery across multiple enterprises, maximizing the efficiency of the machinery.

Figure 3-6 depicts the value of machinery per acre across economic sales classes of farms for the last four Censuses of Agriculture. The value of machinery and equipment for each sales class decreases from the lowest sales classes (excluding very small farms) until sales reach around $100,000-$250,000. At that point machinery values per acre begin to rise, especially in the last three Census years. This may imply that very large farms begin to exhaust size economies, as measured by machinery and equipment values per acre. It is also interesting to observe the upward trend in machinery values per acre on farms. Part of this trend is explained by rising machinery costs. It is also plausible and likely that there is a substitution effect between machinery and labor. As farms have grown in size, machinery may substitute for labor, to capture economies of size.

One plausible explanation for increased machinery values per acre for large farms is that very large farms may have to invest more heavily in machinery to substitute for labor. This may increase the overall value of machinery on very large farms. Another explanation may be that very large farms do not share machinery across farm types or units. Some moderate-size farms may be able to share machinery across enterprise types, and perhaps through partnership agreements. This could be an effect of scope economies at some level. It is interesting that the efficient sales class, where machinery value per acre is maximized, is once again around the $100,000 sales class. This is supporting evidence for economies of size of South Dakota farms.

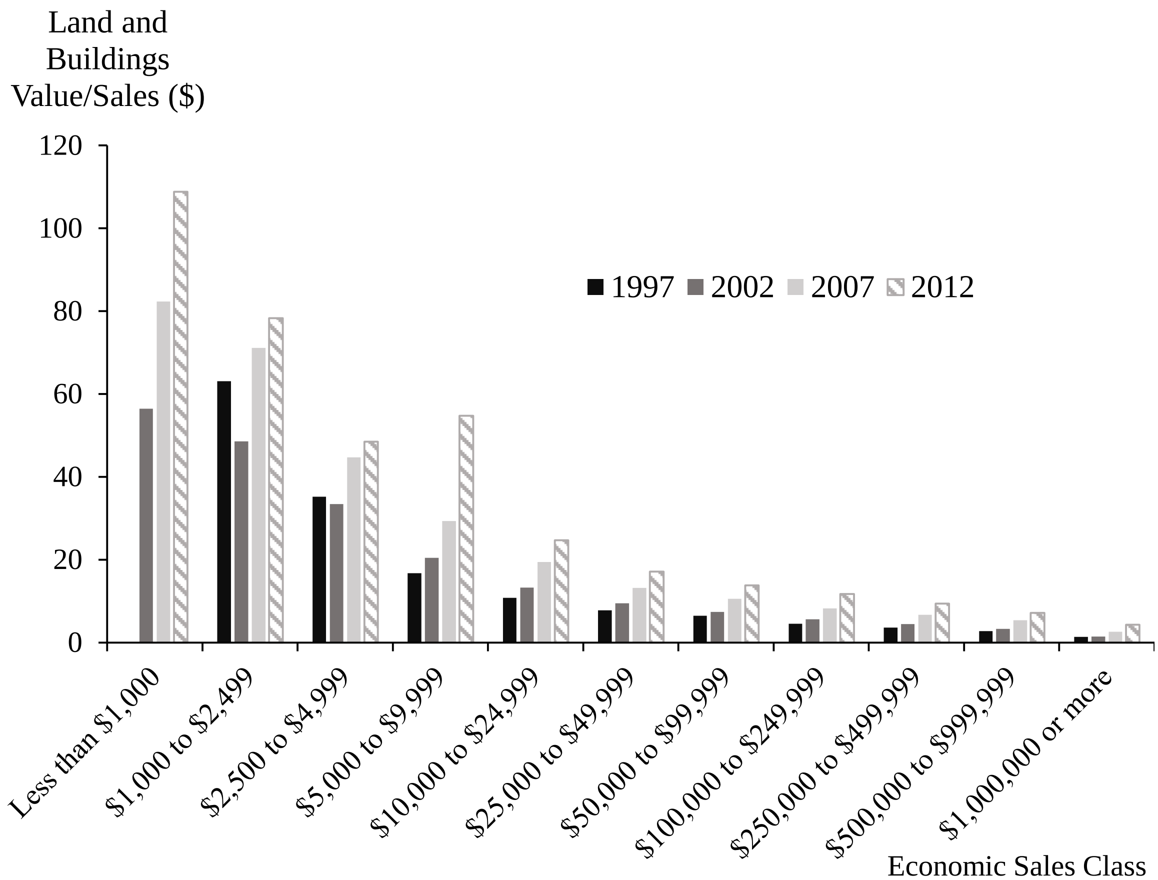
Figure 3-6. Machinery dollars per acre by economic sales class




Source:  Census of Agriculture

Another descriptive statistic that can show evidence for economies of size of farms is the value of land and building per dollar of sales.  Figure 3-7 shows that as farm size increases the value of land and buildings decreases per dollar of sales.  This shows that large farms have higher values of sales compared to the major physical asset on farms, most typically land than do smaller farms.  Producing more sales to the value of land, would help to create efficiencies across a range of farm sizes.

Figure 3-7. Value of land and buildings per sales dollars by sales class




Source: Census of Agriculture

The purpose of the state-wide model descriptive statistics is to show variables that may affect economies of size at the regional level. Because the state-level data are aggregated, more detailed econometric analysis cannot be drawn. The next chapter includes a statistical model that compares economies of size across size groups. The model is an Analysis of Variance (ANOVA) model. This type of model is used to analyze the differences among the group means and their associated variation. This is used to test whether the means of the size classes of farms are equal. If the means are shown to not be equal, there is statistical evidence that there is economies of size.

## County-Level Model

Based on the findings from the state-level model, a county level model is developed to statistically test differences in farm efficiency, both temporally and spatially. Variables in the state-level model that were found to affect farm efficiency are included in the county-level model. Specifically in the county model, this research seeks to find variables that affect farm efficiency at the regional level. Specific crop enterprises, and the typical size of farms either by county or by region may affect the efficiency of farm production.

Based on findings from the state-wide statistics, factors such as the number of farms with sales over $100,000 and the value of machinery and equipment on farms may influence regional efficiencies, as measured by economies of size. Additionally, by comparing values of crop and animal receipts on farms there may be evidence of economies of scope at the regional level. For example, certain regions of South Dakota have higher levels of enterprise diversity than others. By using the value of crop receipts compared to the level of livestock receipts, a proxy for regional diversity is created.

The county-model seeks to find areas of growth that are influenced by economies of size and scope. By observing trends, explanations for regional efficiencies can be deduced. Additionally, insights into future growth may be postulated. If certain regions of South Dakota have seen farm growth, or there is evidence for increasing farm size, predictions of trends may be made. This is important for several reasons. First, the aggregate amount of agricultural land is fixed. Therefore, if farm size were to continue to increase, consolidation and mergers of farms are a possible recourse. Alternatively, if regions of South Dakota seem to have maximized economies of size, future farm growth may be hampered. However, in that case it is important to note that economies of size are not the only reason for farm size increases. Most notably, the search for higher profits, even after exhausting economies of size, is typical of continued farm size increases.

The dependent variable in the county-wide model is expenses per dollar of sales. This is similar to the state-wide model with one exception. The sales for each county includes “other imputed income” as reported by the Bureau of Labor Statistics. As mentioned previously, South Dakota experienced drought conditions during 2002 and 2012, during two of the Census years included for this research. Because of the drought, reported income during the 2012 Census of Agriculture was below what was actually received during that year. For example, many insurance and disaster payments were received after Census surveys were completed and sent back to NASS. This led to regional variations in reported farm sales and income across South Dakota in 2012. To account for these indemnity payments, the BEA “other imputed income” was included.

For example, “other imputed income” for South Dakota was $212 million in 1997, $374 million in 2002, $478 million in 2007, and $1.5 billion in 2012. By including this income, regional indifferences in farm sales affected by the drought are accounted for. Additionally, it controls for the temporal difference in indemnity payments that was most pronounced in 2012.

## Model Estimations

The software used to analyze the models in this research is a common econometric modeling system, STATA©. This is one of the most commonly used econometric modeling systems used in economics today. STATA© allows for quick and simple data transformations, and has built-in commands for testing for common econometric issues such as heteroskedasticity and autocorrelation.

The data in this research was downloaded into Microsoft Excel© from the previous four Census of Agriculture, that include the 1997, 2002, 2007 and 2012 Census of Agriculture. Data from Excel© was then downloaded into STATA© for analysis.

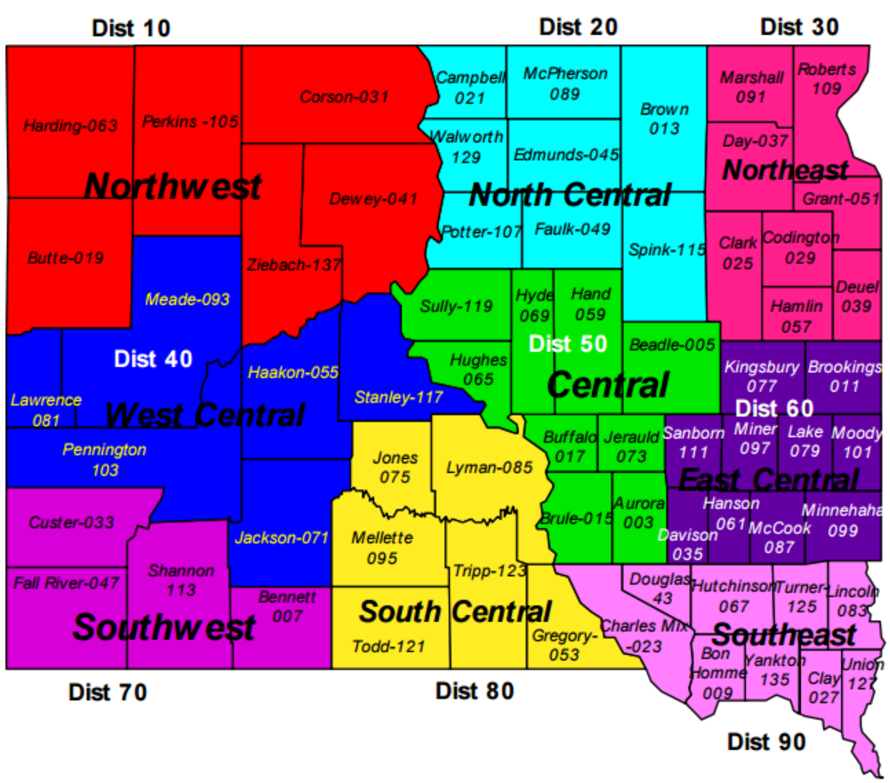
## Chapter IV: Results and Discussion

This section of the research first reports statistics from the Census of Agriculture to give an overview of farm level data in South Dakota. Following the reporting and discussion of the statistics, the results from the models described in Chapter III are presented and discussed.

### South Dakota Farm Regions

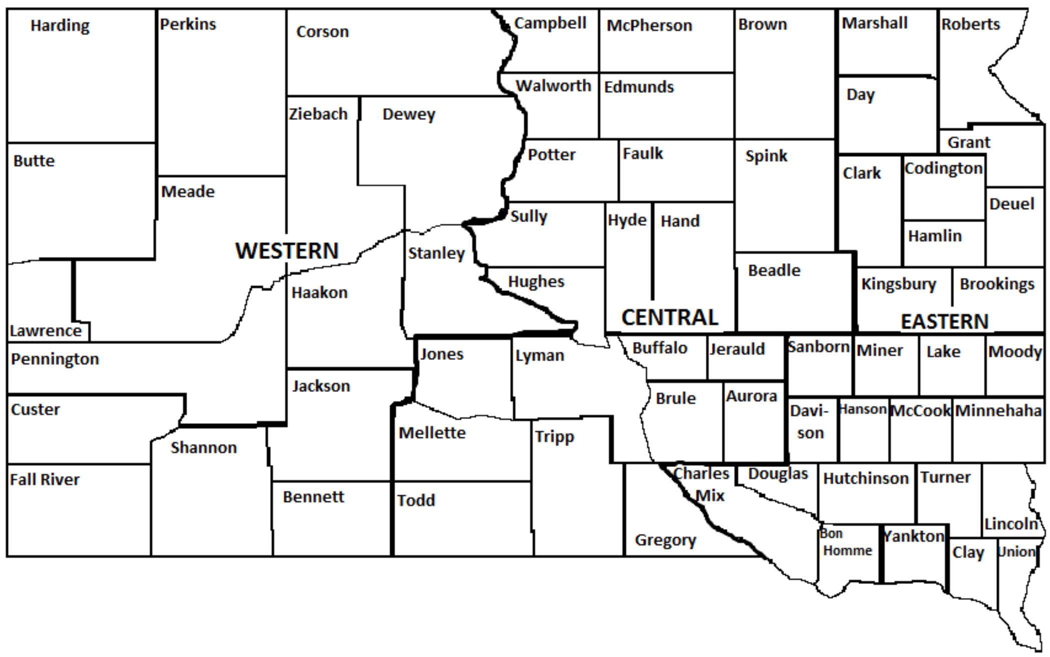
South Dakota consists of 66 counties. NASS classifies nine agricultural districts in South Dakota: northwest, north central, northeast, west central, central, east central, southwest, south central, and south east (Figure 4-1). These districts can be aggregated to region for discussion as: western, central, and eastern (Figure 4-2).

Figure 4-1. South Dakota agriculture reporting districts




Source: NASS

Figure 4-2. Broad regions of South Dakota




It is helpful to understand the scope and diversity of farm production across South Dakota. Therefore, farm numbers, size of farms, and enterprises are discussed below for each of the three main regions.

## Western Region

Data from the 2012 Census of Agriculture show that there were 5,988 farms in the counties included in the western region. Meade County had the largest number of farms at 891. Average net cash farm income ranged between $3,000 and $150,000 in 2012. Farms in western South Dakota tend to be the largest in the state, with county-based average farm size ranging from about 500 acres in Lawrence County to over 6,000 acres in Shannon County.

Western South Dakota is typically considered cattle country, because of large expanses of land suitable for livestock grazing. In 2012 there were 3,824 farms that had cattle and calves inventory in the Western region. This is approximately 64% of all farms in the region.

Conversely, there are fewer grain farms in western South Dakota. In 2012 there were 503 farms (8%) that harvested corn for grain, 16 farms (0.3%) that harvested soybeans, and 921 farms (15%) that harvested wheat. The most common crops harvested were hay, haylage, grain silage, and greenchop, at 2,775 farms (46%).

### Central Region

There were 8,828 farms in the Central region of South Dakota in 2012. Brown County had the largest number of farms at 1,056. Average net cash farm income ranged from roughly \$50,000 to \$350,000 by county in 2012. The average size of farms in the Central region ranged from 1,000 acres in Aurora County to over 3,000 acres in Sully, Buffalo, Jones, Mellette, and Todd Counties.

Farms in central South Dakota have a diverse mix of enterprises. In 2012 there were 4,445 farms with cattle and calves inventory (50%), 3,830 farms that harvested corn for grain (43%), 3,062 farms that harvested soybeans (35%), 2,088 farms that harvested wheat for (24%), and 4,483 farms that harvested all hay and haylage products (51%).

### Eastern Region

The Eastern region of South Dakota had the largest number of farms in South Dakota by region in 2012 with a total of 17,173. Specific to the region, Minnehaha County had the largest number of farms at 1,157. Average net cash farm income ranged from roughly \$50,000 to \$150,000 by county in 2012. Farms in the Eastern region tend to be smaller, with the average county farm size ranging from 353 acres in Minnehaha County to 1,027 acres in Marshall County.

Farms in the Eastern region of South Dakota primarily grow cash grains, with corn and soybeans making up the largest portion of cash grains grown. However, in 2012 there were 7,314 farms (43%) that had cattle and calves inventories. During 2012 there were 7,927 farms that harvested corn for grain (46%), 7,859 farms that harvested soybeans (46%), 1,795 farms that harvested wheat (10%), and 7,437 farms that harvested hay or haylage (43%).

## Growth in Farm Size

Part of this research focuses on the growth in farm size in South Dakota, and how economies of size and scope may explain farm growth. Brown et al. (2015) provide an overview of long-term structural changes in South Dakota agriculture. During the last 80 years South Dakota farm numbers have decreased by over 60 percent, and the average size farm has increased by over 200 percent (Table 4-1). The decreasing number of farms and increasing farm size is an important topic in agriculture.

In Brown et al. (2015), descriptive statistics were provided to show past structural trends in South Dakota agriculture. An objective of this research is to use past data to predict changes in South Dakota agriculture. By modeling farm efficiency as a function of farm size, diversification, and location this research may be able to predict trends. This would be important for not only policy makers at the state level, but for policy makers, businesses and producers at the regional level. For example, if cost efficiencies are shown for varying enterprises in specific regions of the state, decision makers may be more informed for future changes.

Table 4-1. South Dakota farm statistics, 1935-2012

| Census Year | Number of Farms | Net Change in Number of Farms | Annual Rate of Change | Land in Farms (Thousands of Acres) | Average Farm Size (Acres) |
|---|---|---|---|---|---|
| 1935 | 83,303 | | | 37,102 | 445 |
| 1940 | 72,454 | -10,849 | -2.8% | 39,474 | 545 |
| 1945 | 68,705 | -3,749 | -1.1% | 43,032 | 626 |
| 1950 | 66,452 | -2,253 | -0.7% | 44,786 | 674 |
| 1954 | 62,520 | -3,932 | -1.5% | 44,949 | 719 |
| 1959 | 55,727 | -6,793 | -2.3% | 44,850 | 805 |
| 1964 | 49,703 | -6,024 | -2.3% | 45,567 | 917 |
| 1969 | 45,726 | -3,977 | -1.7% | 45,584 | 997 |
| 1974 | 42,825 | -2,901 | -1.3% | 45,978 | 1,074 |
| 1978 | 39,655 | -3,170 | -1.9% | 44,543 | 1,123 |
| 1982 | 37,148 | -2,507 | -1.6% | 43,811 | 1,179 |
| 1987 | 36,376 | -772 | -0.4% | 44,157 | 1,214 |
| 1992 | 34,057 | -2,319 | -1.3% | 44,828 | 1,316 |
| 1997 | 33,191 | -866 | -0.5% | 44,142 | 1,330 |
| 2002 | 31,736 | -1,455 | -0.9% | 43,785 | 1,380 |
| 2007 | 31,169 | -567 | -0.4% | 43,666 | 1,401 |
| 2012 | 31,989 | 820 | 0.5% | 43,257 | 1,352 |

Sources: Adapted from Brown et al. (2015) and Census of Agriculture

The declining number of farms and the growth in average farm size has occurred for many decades. Table 4-1 shows that since 1935 the number of farms has decreased between every Census until the 2012 Census. Farm size has followed a similar trend, with the average size of South Dakota farms increasing between every Census, except between 2007 and 2012. Between 2007 and 2012, the number of very small farms increased in South Dakota (typically fewer than 100 acres), which led to a small increase in farm numbers, and a small decrease in the average size farm.

The decrease in the number of farms is not limited to a specific region of South Dakota. Table 4-2 shows that farm numbers in South Dakota have declined over time in each region of South Dakota by similar percentages. Between 1935 and 2012 the number of farms in the Western region of South Dakota decreased by 1.4% annually on average, while the number of farms decreased by 1.6% and 1.3% annually on average for the Central and Eastern regions of the state, respectively. What this shows is that farm consolidation and growth are not limited to specific areas in South Dakota. As mentioned previously, South Dakota has a very diverse farm landscape, mostly denoted by geography. The fact that farm numbers have decreased by similar proportions across the state show that all types of farm enterprises have seen decreases in farm numbers and increases in farm size and consolidation.

Table 4-2. South Dakota farm numbers by region over time

| South Dakota Region | Thousands of Farms | | | | | | |
|---|---|---|---|---|---|---|---|
| | 1935 | 1950 | 1964 | 1978 | 1992 | 2002 | 2012 |
| Western | 15.2 | 9.2 | 6.7 | 5.9 | 6.2 | 5.8 | 6.0 |
| Central | 25.6 | 19.3 | 13.9 | 11.2 | 10.0 | 9.0 | 8.8 |
| Eastern | 42.5 | 38.0 | 29.1 | 21.7 | 17.9 | 16.9 | 17.2 |
| State | 83.3 | 66.5 | 49.7 | 38.8 | 34.1 | 31.7 | 32.0 |
| | 1935-1950 | 1950-1964 | 1964-1978 | 1978-1992 | 1992-2002 | 2002-2012 | 1935-2012 |
| | Average Annual Percent Change During Period | | | | | | |
| Western | -3.4% | -2.3% | -0.9% | 0.3% | -0.5% | 0.3% | -1.4% |
| Central | -1.9% | -2.4% | -1.6% | -0.8% | -1.0% | -0.3% | -1.6% |
| Eastern | -0.7% | -1.9% | -2.1% | -1.4% | -0.6% | 0.2% | -1.3% |
| State | -1.5% | -2.1% | -1.8% | -0.9% | -0.7% | 0.1% | -1.4% |

Source: Adapted from Brown et al. (2015) and Census of Agriculture

## State-Level Model Results

In this section results are reported from the state-level STATA© analysis. The results are reported in Table 4-3 and Table 4-4. The state-level model is an ANOVA model. This type of model measures whether there is any statistical difference in costs per dollar of sales between each size class of farms. Data from the different Census years were grouped together in a pooled cross-section data set.

To test whether there are any measurable cost-efficiencies between size groups, the middle size class (sales of $25,000 to $49,000) was used as the control size class. In any comparative statistical test, such as dummy variable tests, one variable must be left out as a control and to avoid multicollinearity. The middle size class was chosen as it offers a straightforward comparison between small and large farms. In addition, a dummy variable for each year was included in the model to control for variations in cost efficiencies between years. The control year was 2012. This year was used because of a large drought that occurred in South Dakota that may have affected costs and returns.

Based on Table 4-3 the only size class of farms that showed any statistically significant differences in costs, as measured by cost per dollar of sales, was the smallest size class of farms. This was significant at the 99% confidence level (p-value=0.01). The coefficient can be interpreted as follows: the smallest size class of farms has cost per dollar of sales that are $9.75 higher than farms with sales between $25,000 and $50,000.

The rest of the size classes do not have statistically significant coefficients. This can be explained by a lack of observations, which increases the size of the standard errors for each observation. This is a common problem in econometric modeling, and was a limiting factor in the state-level model. There were only 44 observations in this model, which reduces the efficiency of the results. It is also important to note that there were no statistically significant differences between each of the Census years, as measured by the yearly dummy variables. However, the same issue applies to these results, i.e., a lack of observations.

Even though the majority of the size classes was not statistically significant, there is an interesting trend in the results. The range of farm sizes below $25,000 in sales had positive signs on their coefficients, and the range of farm sizes above $50,000 in sales had negative signs on their coefficients. This shows that as farm size increases, the cost per dollar of sales does decrease.

One way to mitigate the lack of observations, which increases the standard errors, was to group the size classes into three categories. These three categories were labeled small farms (sales less than $10,000), medium farms (sales $10,000 to $250,000) and large farms (sales $250,000 and above). Table 4-4 displays the results from that model. Using the small size class as the control size, medium and large farms in South Dakota have costs that are $3.47 and $3.68 less per dollar of sales than small farms, respectively. These results are also significant at a 95% confidence level. Although this is a limited sample, it provides support to what was shown descriptively in Chapter III for the state-level model.

Table 4-3. State-level model results

| Size Class | Coefficient | P-Value |
|---|---:|---:|
| Less than $1,000 | **9.751** | (.010) |
| $1,000 to $2,499 | 2.323 | (.515) |
| $2,500 to $4,999 | 1.098 | (.757) |
| $5,000 to $9,999 | .593 | (.867) |
| $10,000 to $24,999 | .220 | (.951) |
| $25,000 to $49,999 | CONTROL | CONTROL |
| $50,000 to $99,999 | -.114 | (.974) |
| $100,000 to $249,999 | -.206 | (.954) |
| $250,000 to $499,999 | -.249 | (.944) |
| $500,000 to $999,999 | -.261 | (.941) |
| $1,000,000 or more | -.222 | (.950) |
| | | |
| Year dummy variables | 4 | |
| R-squared | .357 | |
| Obs. | 44 | |

*Bolded coefficients are significant at the 0.05 or greater. Numbers in parenthesis are p-values for coefficients. Year dummy variables include 1997, 2002, 2007, and 2012 to control for fixed effects.

Table 4-4. State-level by grouped size class

| Size class | |
|---|---|
| Small | CONTROL |
| | CONTROL |
| Medium | **-3.466** |
| | (.059) |
| Large | **-3.685** |
| | (.063) |
| Year dummy variables | 4 |
| R-squared | 0.168 |
| Obs. | 44 |

Note: Small class equals sales less than $10,000. Medium equals sales $10,000-$250,000. Large equals sales greater than $250,000.
*Bolded coefficients are significant at the 0.05 or greater. Numbers in parenthesis are p-values for coefficients. Year dummy variables include 1997, 2002, 2007, and 2012 to control for fixed effects.

## County Level Model Results

The purpose of the county-level model analysis is to statistically test variables that may be influencing economies of size and scope of South Dakota farms. These variables were postulated in Chapter III. They include the proportion of farms with sales over $100,000, value of machinery and equipment, and relative enterprise diversity on farms. Also included in the model are a proxy for full-time farm operators and a control variable for land values.

Table 4-5 shows the means of the dependent variable in the county-level model. That is, dollars of expenses per dollar of sales. This is the same type of ANOVA model that was used in the state-level analysis. This allows for making a statistical comparison of economies of size across agriculture districts in South Dakota.

The agriculture districts that were found to be statistically different in terms of economic efficiency are shown in Table 4-5. For example, in column (1) farms in the

North Central district of South Dakota have expenses that are $0.04 per dollar of sales less than farms in the Central district of the state.

In Table 4-5 the districts that were used as the control are labeled with as *C*. The table mirrors itself across the diagonal. Table 4-5 allows for making comparisons of regional economies of size. Based on these results, the North Central, Central, East Central, Northeast, and South East districts may show evidence of regional farm efficiencies. As previously discussed, these regions are all "east river" and are more crop intensive compared to "west river" areas of South Dakota.

Imputed income, as reported by the BEA, was added to sales. This captures insurance and indemnity payments. This most notably shows up in the yearly variables. 2012 was used as the control. Based on these results there were higher expenses per dollar of sales across all districts in 1997, 2002, and 2007 compared to 2012. The drought in 2012 caused large insurance payments, which partially explains the higher sales values, and therefore lower expenses per dollar of sales in Table 4-5. Thus, there is evidence for economies of size across districts, and farms in South Dakota. This is important and provides justification for this research.

Table 4-5. Comparison of district-level economic efficiency

| **Region** | **(1)** | **(2)** | **(3)** | **(4)** | **(5)** | **(6)** | **(7)** | **(8)** | **(9)** |
|---|---|---|---|---|---|---|---|---|---|
| Central | *C* | .019 | **.041** | .016 | .002 | -.003 | .017 | **-.057** | -.024 |
| | | (.164) | (.004) | (.269) | (.898) | (.870) | (.221) | (.001) | (.122) |
| East Central | -.019 | *C* | .022 | -.003 | -.017 | -.021 | -.002 | **-.075** | **-.042** |
| | (.164) | | (.107) | (.827) | (.267) | (.160) | (.890) | (.000) | (.005) |
| North Central | **-.041** | -0.022 | *C* | -.025 | **-.039** | **-.043** | -.024 | **-.098** | **-.065** |
| | (.004) | (.107) | | (.083) | (.014) | (.006) | (.089) | (.000) | (.000) |
| Northeast | -.016 | .003 | .025 | *C* | -.014 | -.018 | .001 | **-.072** | **-.039** |
| | (.269) | (.827) | (.083) | | (.385) | (.249) | (.934) | (.000) | (.013) |
| Northwest | -.002 | .017 | **.039** | 0.014 | *C* | -.004 | .015 | **-.059** | -.026 |
| | (.898) | (.267) | (.014) | (.385) | | (.789) | (.334) | (.002) | (.126) |
| South Central | .003 | .021 | **.043** | .018 | .004 | *C* | .019 | **-.054** | -.021 |
| | (.870) | (.160) | (.006) | (.249) | (.789) | | (.208) | (.004) | (.206) |
| Southeast | -.017 | .002 | .024 | -.001 | -.015 | -.019 | *C* | **-.074** | **-.040** |
| | (.221) | (.890) | (.089) | (.934) | (.334) | (.208) | | (.000) | (.009) |
| Southwest | **.057** | **.075** | **.098** | **.072** | **.059** | **.054** | **.074** | *C* | .033 |
| | (.001) | (.000) | (.000) | (.000) | (.002) | (.004) | (.000) | | (.078) |
| West Central | .024 | **.042** | **.065** | **.039** | .026 | .021 | **.040** | -.033 | *C* |
| | (.122) | (.005) | (.000) | (.013) | (.126) | (.206) | (.009) | (.078) | |
| 1997 | **0.032** | | | | | | | | |
| | (.002) | | | | | | | | |
| 2002 | **0.087** | | | | | | | | |
| | (.000) | | | | | | | | |
| 2007 | 0.014 | | | | | | | | |
| | (.157) | | | | | | | | |
| 2012 | *C* | | | | | | | | |
| R-squared | 0.335 | | | | | | | | |
| Obs. | 264 | | | | | | | | |

Note: P-values are in parenthesis. Bolded coefficients were found to be statistically significant at the 0.05 percent level or greater.
Source: USDA, NASS

Based on the results from Table 4-5 further analysis was completed to analyze variables that impact economies of size and scope of South Dakota farms. Because certain regions seem to have higher levels of efficiency it is important to include variables that may impact the efficiencies observed spatially. Farm size (as measured by sales) was shown to influence economies of size in Chapter III. Other variables that are postulated to impact economies of size are crop sales compared to livestock sales, and machinery investment on farms. Because Eastern portions of South Dakota have lower expenses per dollar of sales, as shown by Table 4-5, controlling for crop sales and machinery investment is important to distinguish among various enterprises.

The following OLS model is:

$$\widehat{\$expenses/\$sales}_{i,j} = B_0 + B_1 * \frac{county\ crop\ sales}{total\ county\ sales}_{i,j} + B_2 * proportion\ full- time\ operators_{i,j} + B_3 * \frac{farms\ over\ \$100k\ sales}{total\ farms\ in\ county}_{i,j} + B_4 * \log(average\ machinery\ values\ per\ farm)_{i,j} + B_5 * \log(averge\ land\ and\ bulding\ values\ per\ acre)_{i,j} + e\ ,$$

where variables are for county *i* (66 South Dakota counties), and year *j* = 1997, 2002, 2007, and 2012.

Based on results from the county ANOVA model, the percent of total county sales accounted for by crop sales is expected to increase the efficiency in each county. The proportion of full-time operators would be expected to also increase the efficiency. This variable is a proxy for managerial ability; the more time the operator spends on the farm, the greater their propensity for farming expertise. To account for the findings in the state-wide model, the number of farms in each county with sales of $100,000 or greater was included. Because it was observed that efficiency occurs at farm sales of that level, the greater the percentage of farms with sales of $100,000 or greater the more efficient that county may be in aggregate. Machinery values per farm and land values per acre were also included. These values are also logged to make interpretation more convenient. It is postulated that higher machinery values on farms would increase economic efficiency. However, it was also shown that there seems to be diseconomies of size at some point exhausting machinery efficiency. The average per acre value of land and buildings was included to account for variations across regions and enterprise types.

Because the county-level ANOVA model showed that economic efficiency varies by agriculture district the county-level model also includes a control. In STATA, the regression was specified to be clustered by district. This "cluster" command essentially creates robust standard errors to account for variation in the standard error terms by region. This is an appropriate method to use when there is variation within regions, or other clustered data in pooled-cross section data sets. By controlling for this variation, heteroskedasticity of the error terms is eliminated, and the corresponding coefficient results are efficient. This is a very important control for this model. Because efficiency was found to vary by region, and it was previously shown that there are regional differences in crop production, it was controlled for.

Table 4-6 displays the results from the county-level model. The full-model is included in column (1). Crop sales as a percent of total sales and average machinery values on farm where found to be significant. However, the percent of farms with over $100,000 in sales is also close to the 0.05 significance level. The value of land and buildings, and the percent of full-time operators were found not to be statistically significant in the first run of the model, and were dropped from the subsequent models.

The second regression model is included in column (2). This is a parsimonious form of the original OLS model. In this model, both crop sales as a percent of total sales, and percent of farms in each county over $100,000 in sales were found to be significant at the 0.01 level. Column (3) reports the final regression results. Once again both crop sales as a percent of total sales and percent of farms in each county over $100,000 in sales were statistically significant at the 0.01 level.

Based on these findings, for each percent increase in crop sales to total sales in a county, expenses per dollar of sales decrease by $0.12, *ceteris paribus*. This is a relatively high number. However, the range of crop sales as a percentage of total sales is large, which is shown in the descriptive statistics in Table 4-7. For each additional percent increase in farms over $100,000 in sales, expenses per dollar of sales decreases by $0.14, *ceteris paribus*.

Table 4-6. County-level OLS model

| **Variable** | **(1)** | **(2)** | **(3)** |
|---|---|---|---|
| Crop sales as a percent of total sales | **-.161** | **-.138** | **-.120** |
| | (.004) | (.001) | (.002) |
| Percent of full-time farm operators | .091 | | |
| | (.287) | | |
| Percent of farms in county over $100k sales | -.151 | **-.197** | **-.137** |
| | (.081) | (.009) | (.050) |
| Log average per farm machinery values | **.031** | .028 | |
| | (.039) | (.084) | |
| Log average value of land and buildings per acre | .002 | | |
| | (.877) | | |
| Year dummy variables | 4 | 4 | 4 |
| County clusters | 9 | 9 | 9 |
| R-squared | .419 | .414 | .409 |
| Obs. | 264 | 264 | 264 |

*Bolded coefficients are significant at the 0.05 or greater. Numbers in parenthesis are p-values for coefficients. Year dummy variables include 1997, 2002, 2007, and 2012 to control for fixed effects.

Table 4-7. Summary statistics for county-level model

| Variable | Obs. | Mean | Std. Dev. | Min | Max |
|---|---|---|---|---|---|
| Expenses/Sales | 264 | 0.735 | 0.070 | 0.576 | 0.949 |
| Crop sales as a percent of total sales | 264 | 0.449 | 0.195 | 0.014 | 0.895 |
| Percent of full-time farm operators | 264 | 0.295 | 0.079 | 0.108 | 0.494 |
| Percent of farms in county over $100k sales | 264 | 0.356 | 0.109 | 0.072 | 0.664 |
| Average value of machinery per farm ($) | 264 | 152,013 | 85,874 | 35,355 | 595,026 |
| Average value of land and buildings per acre ($) | 264 | 1,101 | 1,065 | 149 | 5,440 |

One final piece of analysis is shown in Figures 4-3 through 4-6. These figures depict the expenses per sales ratio of the 66 counties in South Dakota, compared to the amount of crop sales in each county. This allows for a comparison of enterprise diversity. For example counties that are closer to 1 in the figures, would have a majority of crop sales. Whereas counties that are closer to 0, would have a majority of livestock sales.

The most notable trend begins to occur in 2007, were there is a noticeable shift to more crop sales across counties of South Dakota. This continues into 2012, where the majority of counties in South Dakota have more crop sales compared to livestock sales. It is important to note that sales includes the BEA imputed income, as did the previous analysis of the county-level data. This causes a slight bias, because each county was not weighted by the corresponding amount of imputed income they received. This could mean that counties with a majority of crops are being underweighted in this analysis, or vice versa for counties with majority livestock sales. The main conclusion from these figures is that there is a shift to more crop sales, especially between 2007 and 2012. It also provides a visual example of the efficiency differences in crop sales that was shown in Table 4-6.

Figure 4-3. County crop sales compared to expenses/sales, 1997

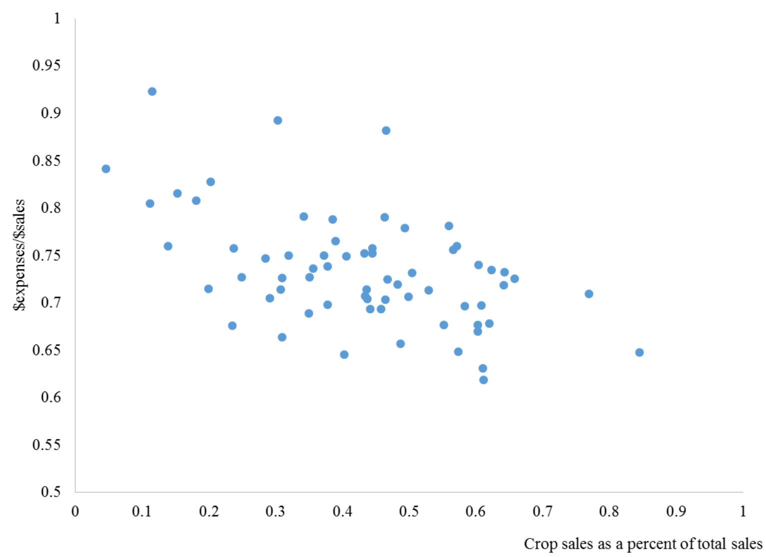



Figure 4-4. County crop sales compared to expenses/sales, 2002

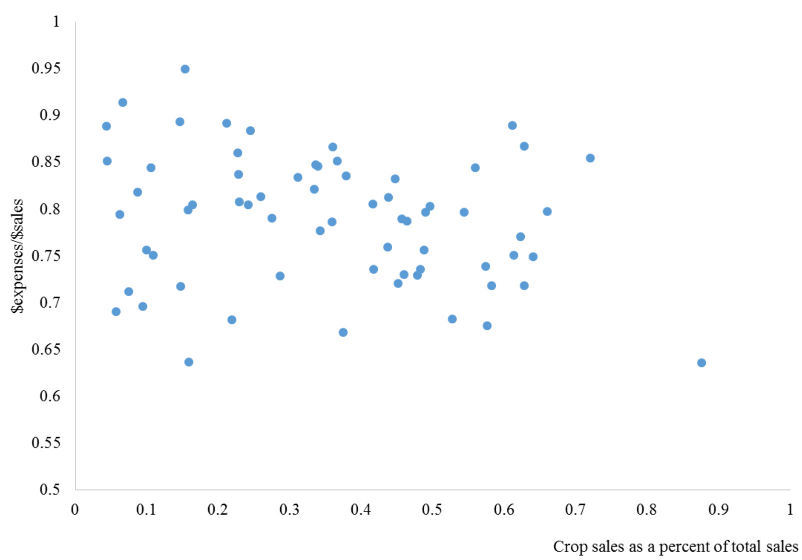


Figure 4-5. County crop sales compared to expenses/sales, 2007

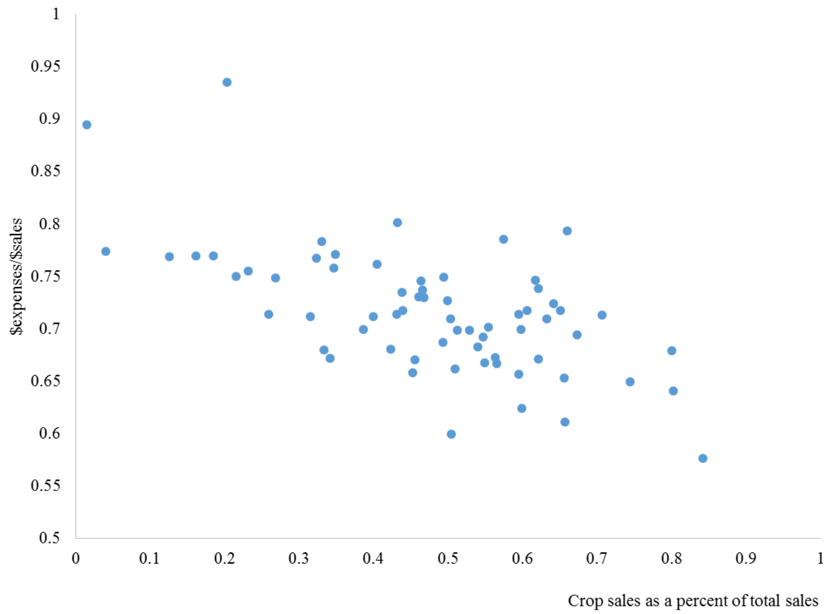
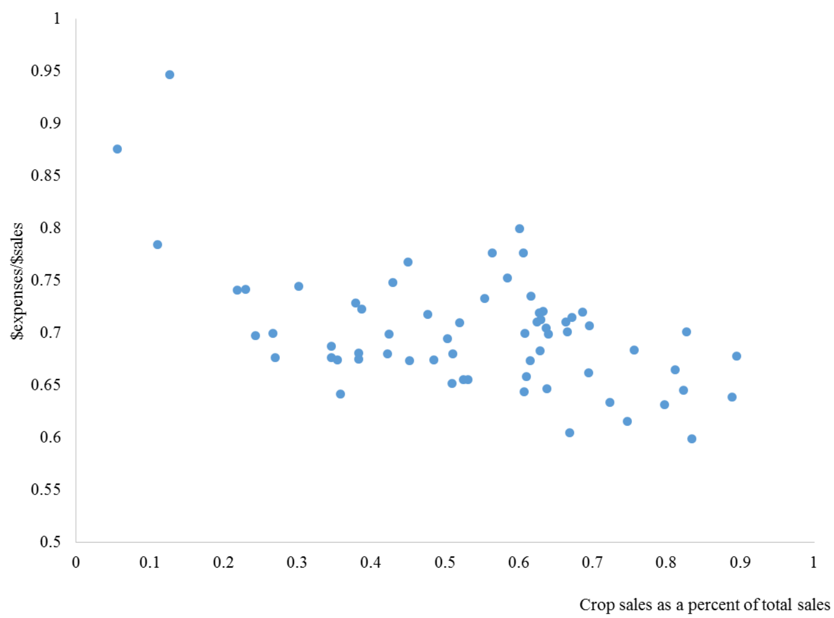



Figure 4-6. County crop sales compared to expenses/sales, 2012



## Chapter V.  Summary and Recommendations

There are two major trends that are currently occurring right now in the agricultural industry in the United States. Farms are increasing in size and the number of farms are decreasing. These occur in tandem, because the amount of land suitable for agricultural production is fixed. These structural changes have been occurring in South Dakota for decades. The number of farms have decreased from over 80,000 in 1935 to just over 30,000 in 2012. During that time frame the average size of farm has grown from 445 acres to 1,352 acres.

While many factors have influenced the growth in farm size, one main explanation is economies of size. Economies of size occurs when a firm decreases per unit cost of production as the size of the firm increases. In the agricultural industry, this may occur when a farm increases its total acres, or its total sales. In this research technical economies of size were analyzed for South Dakota farms, using data from the previous four Census years (1997, 2002, 2007, and 2012). Technical economies of size assume that all firms pay identical input prices, and receive identical output prices. In the farming industry this occurs to a certain extent. Some farm operations may receive volume discounts on their inputs, while others may receive better prices on their outputs. However, farming is one industry that still has “true commodities”. For example, the most common corn crop sold is #2 yellow corn. While there are different varieties of corn, #2 yellow corn grown in Hand County South Dakota, is the same #2 yellow corn that is grown in Brookings County South Dakota.

The overall objective of this research was to empirically test for economies of size and scope for commercial farm operations in South Dakota. The justification of that objective was to provide insights into farm efficiency, past structural changes, and possible future structural changes.

Specific research objectives of this research included, 1) determine the presence of economies of size for the major farm types in South Dakota, 2) determine the presence of economies of scope for South Dakota farms, 3) analyze regional differences of farm size, productivity, and growth across South Dakota, and 4) evaluate the effect of farm size and diversification on farm financial performance.

These objectives were met in the research. However, economies of scope was not analyzed as much as planned. Results were drawn from a state-level model and a county-level model. In the state-level model it was shown that farms in South Dakota reach an economic efficient level near $100,000 in sales and greater. Additionally, as the size of farms increases past that point, overall efficiency does not appear to increase greatly. This is commonly referred to as a an L-shaped average cost curve, where economies of size occur at a certain point, and then level off at sizes greater than the specific size. Implications of this are that nearly 40% of farms in South Dakota are producing at a level that was found to exhibit economies of size.

In the county-level model regional variations in economies of size were found. Counties in the central and eastern parts of South Dakota exhibited economic efficiency levels that were statistically greater than in counties in other parts of the state. Further modeling revealed that the percentage of total county sales accounted for by crop sales, and the percentage of farms in each county that had sales greater than $100,000, impacted the efficiency of farm production.

These findings show that as farm size growth has occurred, areas where farms have previously reached economic efficient levels, i.e., have obtained economies of size, are areas were farms are more efficient. Specific to enterprise diversity, areas that have higher crop sales also seem to show economic efficiency. Therefore, it can be postulated that farm size growth may occur in areas both set for future farm consolidation and increased crop production.

It is important to realize that these results were influenced by structural changes that have occurred in South Dakota agriculture over the last 10 to 15 years. Specifically, increasing plantings of cash crops, mainly corn and soybeans, coupled with increasing prices in those commodities has increased the overall revenue of farms that grow those commodities. This does not invalidate the results in this research, rather it extends the possibilities. If the prices of these commodities continue to remain economically profitable, then farms will capture economies of size by either switching production to these crops, or increasing the size of their operations. On the other hand, if prices for these crops does not warrant intensifying their production, other factors may influence farm efficiency.

## Recommendations

Prior to this research very little formal research has been done regarding economies of size of South Dakota farms. Therefore, there are multiple opportunities to extend this research. The data used for this research was aggregated Census of Agriculture data. While the Census of Agriculture is the most formal and precise survey of all South Dakota farms, aggregated data does have limitations.

Therefore, future research could focus on using industry specific data. This would allow for measurement of economies of size across specific enterprise units. This could possibly include measuring economies of size between corn production, soybean production, corn and cattle production, and other combinations. Additionally, that type of study would allow specific analysis of economies of scope, which may influence economic efficiency more than this research could analyze.

Additionally, this research did not analyze other factors that may cause farms to increase in size beyond the level needed to research economic efficiency. These factors could include the search for higher profits, the goal of adding farm operators (family) to the farm business, and other factors.

It was an underlying goal of this research to begin to analyze economies of size and scope of South Dakota farms, with the hopes of future research extending these findings. This research did find that economies of size are occurring in South Dakota, and economies of size is also influenced by relative enterprise diversity and spatial influences.

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